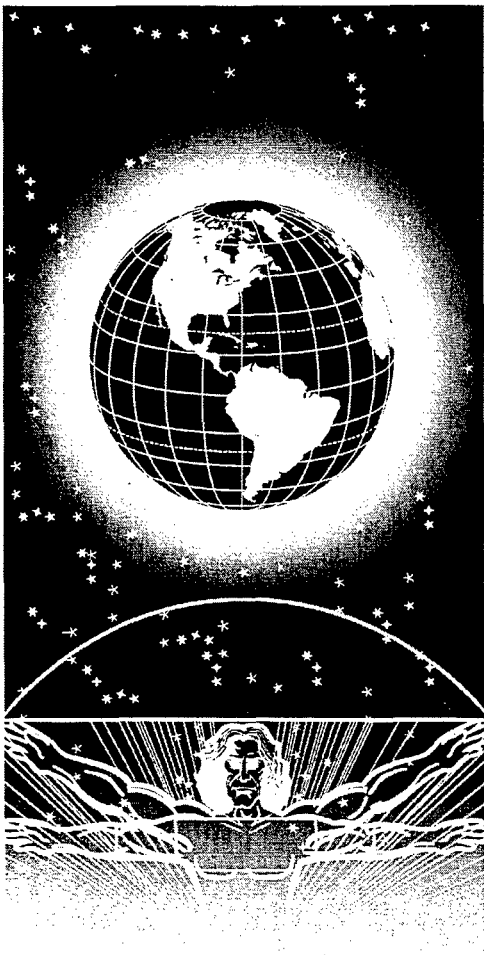


**UNITED STATES AIR FORCE
RESEARCH LABORATORY**

**TPH CRITERIA WORKING GROUP
FIELD DEMONSTRATION: SCOTT AFB,
BELLEVILLE, IL**



Elaine A. Merrill
OPERATIONAL TECHNOLOGIES CORPORATION
1370 NORTH FAIRFIELD RD, SUITE A
DAYTON, OH 45432

October 1998
Interim Report - June 1997 - September 1998

20060630310

**Human Effectiveness Directorate
Deployment and Sustainment Division
Operational Toxicology Branch
2856 G Street
Wright-Patterson AFB OH 45433-7400**

Approved for public release; distribution is unlimited.

STINFO COPY

NOTICES

When US Government drawings, specifications or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Please do not request copies of this report from the Air Force Research Laboratory. Additional copies may be purchased from:

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

Federal Government agencies and their contractors registered with the Defense Technical Information Center should direct requests for copies of this report to:

Defense Technical Information Service
8725 John J. Kingman Rd., Ste 0944
Ft. Belvoir, Virginia 22060-6218

DISCLAIMER

This Technical Report is published as received and has not been edited by the Technical Editing Staff of the Air Force Research Laboratory.

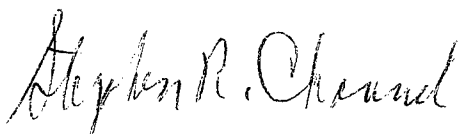
TECHNICAL REVIEW AND APPROVAL

AFRL-HE-WP-TR-1999-0025

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE DIRECTOR



STEPHEN R. CHANNEL, Maj, USAF, BSC
Branch Chief, Operational Toxicology Branch
Air Force Research Laboratory

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE October 1998		3. REPORT TYPE AND DATES COVERED Final Report - June 1997 - September 1998
4. TITLE AND SUBTITLE TPH Criteria Working Group Field Demonstration: Scott AFB, Belleville, IL			5. FUNDING NUMBERS Contract F41624-94-D-9003/008 PE 62202F PR 7757 TA 7757A2 WU 7757A205	
6. AUTHOR(S) E.A. Merrill				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Operational Technologies Corporation 1370 North Fairfield Rd., Suite A Dayton, OH 45432			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Human Effectiveness Directorate Air Force Research Laboratory Wright-Patterson AFB, OH 45433-7400			10. SPONSORING/MONITORING AGENCY REPORT NUMBER AFRL-HE-WP-TR-1999-0025	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) A former underground storage tank site at Scott Air Force Base, Illinois, was selected for a field demonstration of the Total Petroleum Hydrocarbon Criteria Working Group approach. Soil at the site was impacted by a release of JP-8 jet fuel. The Working Group approach assesses total petroleum hydrocarbon (TPH) mixtures in 13 fate and transport fractions and applies best available toxicity criteria to each of the fractions to develop Risk Based Screening Levels (RBSLs). TPH levels detected at the site were very low. The majority of the released JP-8 had been previously excavated during removal of the tanks. With the exception of the volatilization to indoor air pathway, the findings of this risk assessment suggest no further action is necessary. Due to the extremely low levels of volatile organic carbon detected and the fact that there is currently no structure on the site, volatilization to indoor air is not a complete pathway, nor likely to be. The RBSLs developed from the Working Group approach for this site were especially suitable due to the lack of carcinogenic benzene or polycyclic aromatic hydrocarbons detected.				
14. SUBJECT TERMS TPHCWG Risk Based Screening Levels Tier Approach to Corrective Objective			15. NUMBER OF PAGES 56	
Weathered fuels JP-8 field demonstration			16. PRICE CODE	
soil hydrocarbon fractions analytical methods Direct Method				
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED		18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED		19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED
				20. LIMITATION OF ABSTRACT UL

THIS PAGE INTENTIONALLY LEFT BLANK.

TABLE OF CONTENTS

1.0 INTRODUCTION	1
1.1 Objectives	1
1.2 Overview of Working Group Approach.....	1
1.3 Site Description.....	3
1.3.1 Soils	4
1.3.2 Regional Hydrology	4
1.3.3 Previous Investigations	5
2.0 SAMPLING AND ANALYSIS	5
2.1 Soil Sample Collection	5
2.2 Analytical Approach	6
2.2.1 Direct Method	7
2.2.2 Conventional TPH Methods.....	8
2.2.3 Quality Control Analysis	8
3.0 WORKING GROUP TIER 1 RISK ASSESSMENT APPROACH.....	8
3.1 Physical Properties of the TPH Fractions.....	10
3.2 Overview of Toxicity Criteria for Fate and Transport Fractions	12
4.0 ANALYTICAL RESULTS	13
4.1 Direct Method Results	13
4.2 Comparison of Conventional Method and Direct Method Results	14
4.3 BTEX Results	15
4.4 Quality Control Results	16
4.4 Analytical Results Summary	16
5.0 RISK-BASED SCREENING LEVELS.....	17
5.1 Residential Scenario Risk Results	18
5.2 Commercial Scenario Risk Results	20
5.3 Risk Discussion	21
5.4 Comparison with Illinois Regulatory Guidance	21
6.0 CONCLUSIONS	22
7.0 REFERENCES	22
 APPENDIX A ANALYTICAL DATA	 A-1
APPENDIX B RBSL CALCULATION.....	B-1
APPENDIX C RBCA MODEL RUNS.....	C-1

LIST OF FIGURES

Figure 1-1	Site 508	3
Figure 1-2	Location of Scott Air Force Base	4
Figure 2-1	Sample Locations	6
Figure 4-1	Fraction Composition: Direct Method.....	14
Figure 5-1	Exposure Pathway Analysis.....	15

LIST OF TABLES

TABLE 1-1	WORKING GROUP AROMATIC AND ALIPHATIC FRACTIONS.....	2
TABLE 3-1	TPH FRACTIONS DERIVED FROM FATE AND TRANSPORT CHARACTERISTICS AND ASSOCIATED PROPERTIES	11
TABLE 3-2	WORKING GROUP TOXICOLOGY FRACTION-SPECIFIC RfDs.....	12
TABLE 4-1	DIRECT METHOD ANALYTICAL RESULTS	13
TABLE 4-2	SUMMARY OF COMPARATIVE TPH DATA	15
TABLE 4-3	SUMMARY OF BTEX RESULTS BY SW-846 8021A.....	16
TABLE 5-1a	TIER 1 RESIDENTIAL SOIL RBSLs AND HIs USING ONE-HALF THE LOQ FOR NONDETECTS	19
TABLE 5-1b	TIER 1 RESIDENTIAL SOIL RBSLs AND HIs USING ZERO FOR NONDETECTS	19
TABLE 5-2a	TIER 1 COMMERCIAL SOIL RBSLs AND HIs USING ONE-HALF THE LOQ FOR NONDETECTS	20
TABLE 5-2b	TIER 1 COMMERCIAL SOIL RBSLs AND HIs USING ZERO FOR NONDETECTS	20
TABLE B-1	TIER 1 DEFAULT EXPOSURE FACTORS	B-4
TABLE B-2	PARAMETERS FOR CROSS-MEDIA RBSL CALCULATIONS.....	B-7

PREFACE

This effort was performed by Operational Technologies Corporation (OpTech) under U.S. Air Force Contract Number F41624-94-D-9003/008. OpTech activities were conducted under the Project Management of Mr. Erik Vermulen, 1370 North Fairfield Road, Suite A, Beavercreek, Ohio 45432. Lt Col (select) Steve Channel of the Operational Toxicology Branch, Human Effectiveness Directorate, Air Force Research Laboratory (AFRL/HEST) at Wright-Patterson Air Force Base, Ohio, served as contract monitor.

The author gratefully acknowledges Doug Stidham of the 375th Civil Engineering Squadron Environmental Flight (CES/CEV) at Scott Air Force Base, Illinois, for providing site information and assistance in coordinating this effort; and Michael Welsh of AmTech Engineering, Inc., Indianapolis, Indiana, for assistance in sample collection. The author also acknowledges Richard Entz and Del Schumaker of Lancaster Laboratories, Lancaster, Pennsylvania, for analytical results.

LIST OF ABBREVIATIONS AND ACRONYMS

°C	degrees Celsius
AF	Attenuation Factor
atm	atmosphere
ASTM	American Society for Testing and Materials
bgs	below ground surface
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes
C	number of Carbon atoms in hydrocarbon molecule
cm	centimeter
C _{sat}	soil saturation Concentration
DRO	Diesel Range Organics
EC	Effective Carbon number of chemical molecule
EPA	Environmental Protection Agency
FID	Flame Ionization Detector
f _{oc}	fraction of organic carbon in soil
ft	feet
g	gram
GC	Gas Chromatograph
G _s	Specific Gravity
GRO	Gasoline Range Organics
H _c	Henry's law constant
kg	kilogram
K _{oc}	carbon-water sorption coefficient
k _s	soil-water sorption coefficient
L	liter
LOQ	Limit Of Quantitation
mg	milligram
mol	mole
MS	Mass Spectrometry
NA	Not Applicable
NAPL	Non-Aqueous Phase Liquid
ND	Nondetect
OpTech	Operational Technologies Corporation
PAH	Polycyclic Aromatic Hydrocarbon
PID	Photo-Ionization Detector
PF	Partition Factor
ppm	parts per million
RBCA	Risk Based Corrective Action
RBSL	Risk Based Screening Level
RES	Residual Saturation
RfD	Reference Dose
s	second
S	Solubility
TACO	Tiered Approach to Corrective Action Objectives
TPH	Total Petroleum Hydrocarbon
yr	year

TPH CRITERIA WORKING GROUP FIELD DEMONSTRATION: SCOTT AFB, BELLEVILLE, IL

1.0 INTRODUCTION

A Tier 1 Risk-Based Corrective Action (RBCA) analysis was conducted at Site 508, Scott Air Force Base, Belleville, Illinois, to demonstrate the development of alternative risk-based cleanup criteria for petroleum-impacted soils. Site 508 is impacted by JP-8 jet fuel, which leaked from underground storage tanks and/or spilled during fuel transfers.

1.1 Objectives

The work is part of a series of field demonstrations to assess the effectiveness of the Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG or Working Group) approach for evaluating different types of weathered fuel spills in various soil types. To develop risk-based criteria, soils from the site were analyzed by the analytical method recommended by the Working Group to characterize the petroleum present in terms of 13 total petroleum hydrocarbon (TPH) fractions. The results of these analyses were then used in simple fate and transport models for soil exposure pathways provided in the RBCA guidance document (ASTM, 1995). The primary goals of this study were:

1. Calculate risk-based screening levels (RBSLs) using the TPH fractionation results and a Tier 1 RBCA approach.
2. Evaluate site risk using the Tier 1 RBSLs and determine the variability in the RBSLs.
3. Compare Tier 1 RBSLs with state criteria.

A secondary objective to the demonstration was to develop a correlation between the Working Group analytical method and conventional TPH method(s). It is important to note that this analysis was not intended for use in modifying the current TPH cleanup criteria established by the state for the site.

1.2 Overview of Working Group Approach

The Working Group approach is incorporated into the RBCA framework which integrates site assessment with U.S. Environmental Protection Agency (EPA)-recommended risk assessment practices. The elements of a risk assessment include: characterization of the source contamination, identification of pathways through which contaminants move in the environment, identification of existing and potential receptors, and assessment of exposure (ASTM, 1995).

These elements are incorporated into a tiered approach that involves increasingly site-specific levels of data collection and analysis. The initial tier, Tier 1, uses conservative default assumptions and models, some of which are replaced in later tiers (i.e., Tier 2 and 3), by less conservative site-specific assumptions and models. The soil cleanup goals defined for a later tier may be less costly to achieve than those defined by the previous tier. The user reviews the

cleanup goals and decides if the cost of conducting the additional site-specific analyses for the next tier are warranted by the potential reduction in cost associated with a reduced remediation action plan. Hence, the tiered approach is often more cost-effective than traditional approaches under which all sites, regardless of site-specific conditions, are required to conform to uniform standards and procedures.

Presently the Working Group approach focuses only on human health, addressing both carcinogenic and non-carcinogenic risks. The approach recognizes that TPH is comprised of different types or classes of hydrocarbons that differ in chemical structure. The Working Group approach relies on the separation of petroleum into 13 separate fractions, listed in Table 1-1. These fractions are based upon the physical structure of the compounds (aromatic or aliphatic) and the "equivalent carbon (EC) number," which is a function of boiling point, and are determined by the retention time on a gas chromatograph (GC) column relative to n-alkanes of known carbon number. The fractions have been assigned specific toxicological, fate and transport characteristics that are based upon an extensive review of available data for individual compounds or for petroleum mixtures which are representative of the fraction. The data review and rationale used are explained in Volumes 3 and 4 of the Working Group documents (TPHCWG, 1998b and c).

TABLE 1-1 WORKING GROUP AROMATIC AND ALIPHATIC FRACTIONS

Aromatic Fraction	Aliphatic Fraction
EC 5-7 (Benzene)*	EC 5-6
EC >7-8 (Toluene)	EC 6-8
EC >8-10	EC >8-10
EC >10-12	EC >10-12
EC >12-16	EC >12-16
EC >16-21	EC >16-21
EC >21-35	

Notes: * Evaluated only as a carcinogen.

EC - equivalent carbon fractions are determined by the retention time on a GC column, relative to alkane compounds of known carbon number (TPHCWG, 1998)

Within a framework such as the American Society for Testing and Materials (ASTM) RBCA, the toxicity, fate and transport information defined by the Working Group can be used to perform a risk-based analysis of each fraction within the petroleum mixture. The risk associated with the "whole TPH" mixture and the soil and groundwater criteria for the "whole TPH" mixture are then determined by combining the risks associated with individual fractions in accordance with their percent composition in the TPH mixture. A brief discussion of the Working Group approach is provided in Section 3 of this document.

1.3 Site Description

Underground storage tanks 8620 and 8621 were removed from Site 508 in November, 1997. The 50,000 gallon tanks held JP-8 jet fuel. Building 508, which is no longer present, was a pump house for the tanks. One end of each tank laid beneath the building. The tanks remained in service until May, 1997. Both tanks were constructed from $\frac{3}{4}$ inch plate with a corrosion coating on the outside and a painted coating on the inside. At the time of their removal, the tanks were in excellent condition with no evidence of leakage from the tanks themselves. The release is believed to have resulted from old tank piping that was no longer in service, overfills or spills within the area of the tank bed. The quantity of the release is unknown. Over 800 cubic yards of soil were removed during the excavation (AmTech Engineering, 1998). At the time of this study, the excavation was still open and confirmatory sampling was being conducted by AmTech Engineering, Inc. to confirm a recommended closure. A site photo is provided in Figure 1-1.

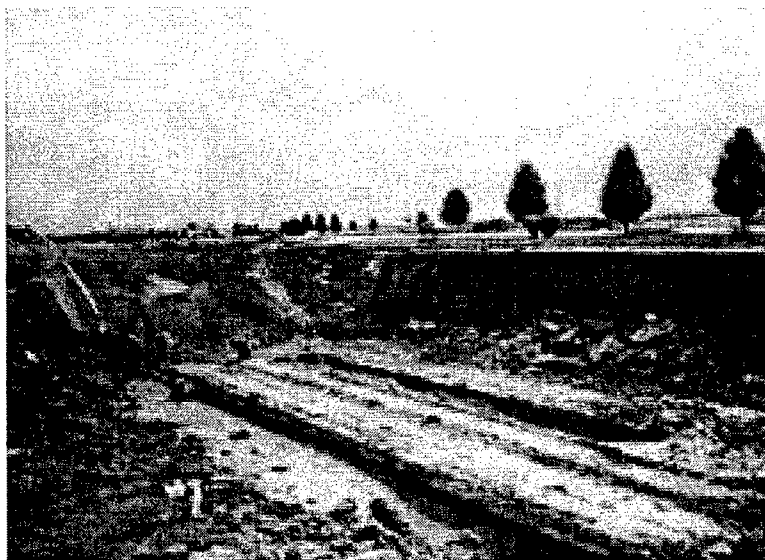


Figure 1-1 Site 508

Site 508 is located in southwestern Illinois at Scott Air Force Base (AFB), approximately 20 miles southeast of St. Louis, Missouri. Scott AFB is located in St. Clair County and is bordered on all sides by agricultural land (see Figure 1-2).

The base receives its potable water from American Water Company, a local municipal water supply from Belleville, IL. The nearest drinking water well is located approximately 1,700 feet southwest of the site (AmTech Engineering, 1998).

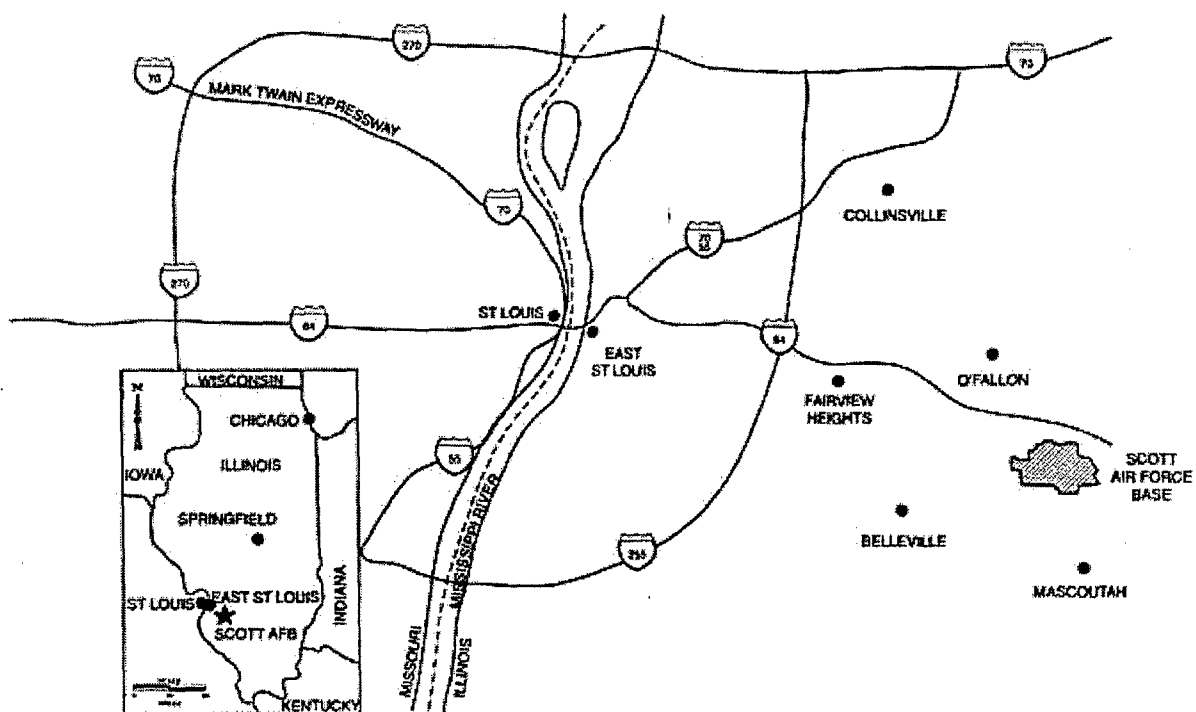


Figure 1-2 Location of Scott Air Force Base

1.3.1 Soils

Soils at the site consist of a reddish-brown to tan silt to fine sandy clay. The surficial geology of Scott AFB, in descending order, consists of eolian, alluvial and glacial deposits. Alluvial deposits include the Cahokia Alluvium, consisting of unconsolidated, variably textured materials ranging from clay to gravel (AmTech Engineering, 1998). Surface soil at the site can be described as a greenish-black, silty clay with some brown mottling. The surface soil was soft and plastic containing abundant roots. The subsurface soil sampled from the impacted zone consisted of a yellowish-brown, very silty clay with bluish-gray staining and a slight petroleum odor. The average moisture content of the soil sampled during this demonstration was 21.5% (see Appendix A).

1.3.2 Regional Hydrology

Scott AFB lies in an area of western Illinois where aquifers of regional significance do not exist. However, the bedrock and unconsolidated units are often used locally as a source of potable water. The uppermost bedrock units at Scott AFB are 85 to 350 ft below ground surface (bgs) and are of Pennsylvanian Age. They consist primarily of non-water-bearing shale with thin, discontinuous beds of sandstone and limestone. The sandstone and, more rarely, the limestone yield small domestic water supplies, with recharge to these strata thought to occur from overlying unconsolidated material. Groundwater movement through these strata is generally to the southeast towards deeper parts of the Illinois Basin. Water-bearing fractures

likely occur in the upper 50 ft of the bedrock (Environmental Resources Management, Inc., 1992).

Underlying the Pennsylvanian strata is the Chesterian Series (Mississippian Age) which includes water-yielding sandstones. The city of Belleville used these sandstones as a water supply prior to acquiring water from the Illinois-American Water Company. The static water level of wells finished in the Mississippian sandstone's reportedly ranged from approximately 175 to 200 ft bgs (Environmental Resources Management, Inc., 1992).

1.3.3 Previous Investigations

At the time of the excavation (November, 1997), soil samples collected from around the tank beds were analyzed for benzene, toluene, ethylbenzene and xylenes (BTEX) and polycyclic aromatic hydrocarbons (PAHs). Benzene levels detected ranged from nondetect (ND) to 0.0021 mg/kg, ethylbenzene ranged from ND to 0.012 mg/kg, toluene ranged from ND to 0.0022 mg/kg and xylenes ranged from ND to 0.026 mg/kg. PAHs exceeded slightly Illinois Tier 1 Residential TACO levels for benzo(a)pyrene (0.230 mg/kg) and dibenzo(a,h)anthracene (<0.220 mg/kg) (AmTech Engineering, 1998).

On May 4, 1998, soil samples along the north and south walls of the excavation area were collected by AmTech Engineering, Inc. and analyzed for BTEX and PAHs. BTEX were not detected. One hit of pyrene was detected at 0.18 mg/kg, which is well below the Illinois Tier 1 TACO level of 12 mg/kg (Illinois EPA, 1997).

2.0 SAMPLING AND ANALYSIS

2.1 Soil Sample Collection

Soil samples were taken from approximately eight to nine ft bgs, two feet into the walls of the excavated pit using a backhoe. For safety reasons, personnel were not allowed into the pit. Locations were chosen based upon visual staining and photo-ionization detector (PID) readings. PID readings were taken from grab samples collected in plastic bags and allowed to volatilize for several minutes. Greenish-black staining extended partially around the excavation's walls between seven to ten ft bgs; stains were most predominant along the east and south sides of the pit closest to the area where the tanks piping was located. Background soil samples were submitted for total organic carbon analysis and matrix spikes. Samples submitted for gasoline range organics and diesel range organics (GRO and DRO) analyses and fractionation were collected from the content of the backhoe and apportioned into sampling jar with minimal head space. Samples for BTEX analysis were collected in accordance with Method 5030, using a syringe to collect the samples, which were then placed into sample jars containing methanol. All samples were stored on ice and shipped the same day via overnight express to the analytical laboratory.

Sample numbers were assigned by location relative to the drive on the west side of the site and the side of the excavation from which the sample was obtained (Figure 2-1). For example E45S8-1 indicates a location that is 45 ft east of the drive on the south side of the excavation

and eight ft bgs. The last digit, -1, designates the sampling sequence. Samples with a BE designation were taken in an area adjacent to, but unaffected by, the JP-8 release.

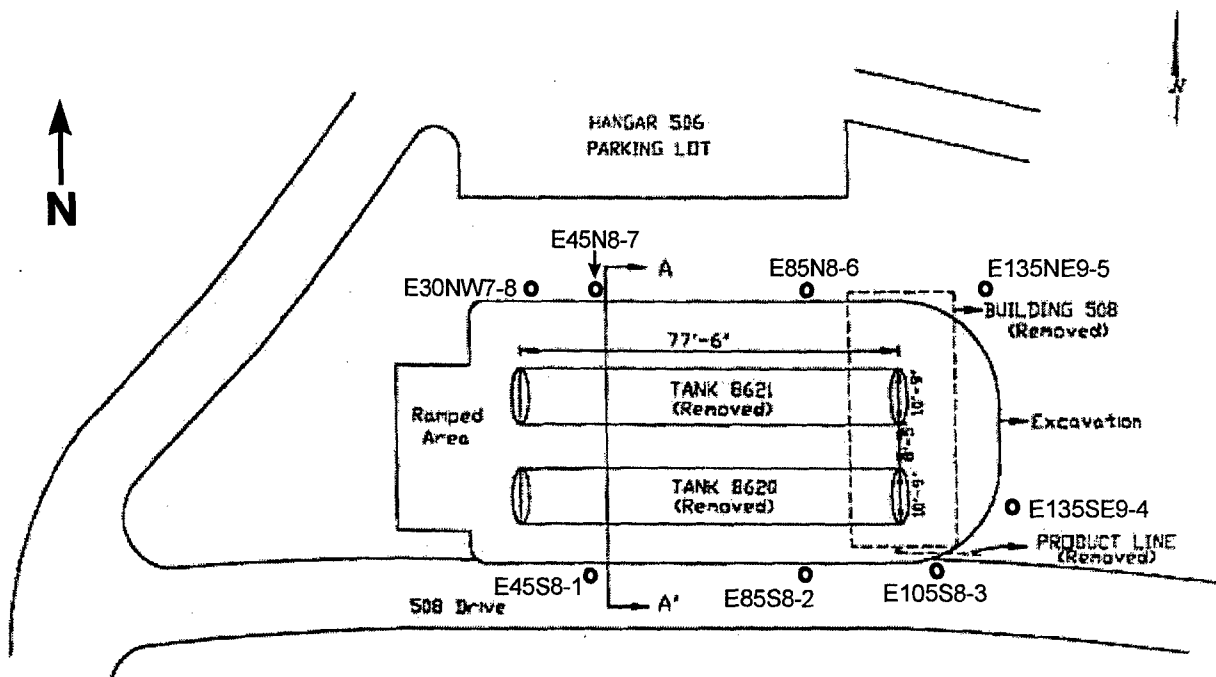


Figure 2-1 Sample Locations

2.2 Analytical Approach

Several analytical techniques are available for measuring TPH in the environment. Many methods are designated by the range of compounds they analyze, such as GRO and DRO. Identifying the method with a particular petroleum product is often only useful to indicate a specific carbon range for the method. As an example, GRO methods typically quantify over an effective hydrocarbon range of EC6 through EC10 or EC12 and standardize against gasoline. A gasoline standard can be used to quantify other hydrocarbon products present in this range (e.g., naphthas, light mineral spirits or Stoddard solvent), but the presence of gasoline-range hydrocarbons in a sample does not indicate that gasoline is actually present. JP-8 jet fuel has components spanning both the GRO and DRO. Using either a gasoline or a diesel method to identify a fuel that spans both the typical gasoline (EC6 through EC12) and diesel (EC12 through EC24) carbon ranges may be misleading since a part of the petroleum mixture is present in each of these ranges, resulting in some overlap and overestimation of TPH concentrations.

Some methods measure more of the TPH present than other methods due to more rigorous extraction techniques or more efficient solvents. Infrared methods, such as EPA Method 418.1, are also subject to interference from naturally-occurring organic materials present in topsoil. This interference can result in predictions of higher TPH concentrations than are actually present.

Therefore, single TPH concentration measurements do not appropriately specify risk. The same concentration of TPH at two different sites may represent very different mixtures. One may include carcinogenic hydrocarbons while the other doesn't. Likewise cleanup criteria based on conventional TPH measurements do not correlate well to risk. An accurate assessment of risk is based on an understanding of the toxicological effects of the compound(s) present in the environmental media. As a result, many TPH criteria were based on aesthetic, analytical method reporting limits or other non-risk based criteria in conjunction with an assessment of carcinogenic indicator compounds. Non-risk-based criteria can lead to unnecessary remediation in many instances. It is important to note however, that human health risk is not always the driving factor in establishing cleanup levels. In some cases, aesthetics, ecological risk or other criteria may be required to determine appropriate cleanup levels.

The Working Group's Volume 1 "Analysis of Petroleum Hydrocarbons in Environmental Media" includes a concise discussion of analytical methods currently available for use in evaluating petroleum contaminated soils and waters (TPHCWG, 1998a). These methods are principally based on the use of gas chromatography; however, several methods are based on infrared spectrometry, gravimetry, immunoassay, thin layer chromatography and high performance liquid chromatography. Discussions on the limitations of each method for use in risk assessments are also provided.

Both a conventional TPH method and the Working Group analytical method were performed on samples from Site 508. The Direct Method, described below, was developed by the Working Group specifically for use within a risk-based framework. The Direct Method provides results for aromatic and aliphatic TPH fractions, grouped into the 13 designated effective carbon ranges (Table 1-1).

2.2.1 Direct Method

The Direct Method uses a tiered approach to determine values for TPH in a single analysis for the EC6 to EC28 range. The sample is extracted with n-pentane and analyzed using a GC with a flame ionization detector (FID) to obtain a direct "whole" TPH measurement. This analysis can also be used to determine the nature of hydrocarbons present or to "fingerprint" the type or types of contamination. If samples are similar, a few may be chosen for further characterization by separation of aliphatic and aromatic fractions which are then analyzed in a manner similar to the whole extract.

After the initial analysis, a portion of the n-pentane extraction is separated into aliphatics and aromatics prior to the fractionation analysis. This separation procedure is either done using alumina (modified EPA Method 3611B) or silica gel (modified EPA Method 3630B or C), which can be used to fractionate petroleum materials into saturates, aromatics and polars. The Direct Method is similar to these methods except that a smaller column is used to minimize dilution and n-pentane is used for extraction and to elute the aliphatics. The use of n-pentane instead of n-hexane allows for the determination of TPH starting at and including n-hexane (n-EC6). Methylene chloride is used to elute aromatics from alumina and a mixture of methylene chloride and acetone is used for elution of aromatics from silica gel.

Following separation of the aromatics and aliphatics on the alumina or silica gel column, fractionated extracts are analyzed by GC/FID. In cases where light-end constituents (i.e., < n-EC9) are observed, GC/mass spectrometry (MS) is performed, especially for the quantitation of BTEX using standard EPA Method 8020 or 8021A.

The Direct Method may not be needed to analyze all soil samples collected at a petroleum contaminated site, but only enough samples necessary to identify the contaminants present at the site. In other words, once petroleum contamination has been fully characterized at a site, additional sampling can rely on traditional, less expensive TPH analysis rather than the Direct Method (if the TPH fingerprint is similar across the site). In addition, application of traditional EPA analytical methods is likely to be necessary to quantify the presence of indicator hydrocarbons such as carcinogenic PAHs.

2.2.2 Conventional TPH Methods

Conventional TPH methods performed during the field demonstration included TPH-DRO by the SW-846 8015B method, TPH-GRO according to the API protocol and BTEX by SW-846 8021A. EPA Method 8015B uses methylene chloride extraction. The extraction is quantified for DRO by peak area comparison of the sample pattern to that of the laboratory's #2 Fuel Oil reference standard (between EC10 to EC28). The quantitation for GRO was performed using the total peak area of the sample pattern between 2-methylpentane and 1,2,4-trimethylbenzene.

2.2.3 Quality Control Analysis

To verify the recovery of individual aliphatic and aromatic hydrocarbon fractions, duplicate spike analyses were performed on a background sample, collected near to, but outside of, the impacted area. Results were compared to acceptable matrix spike recoveries for semivolatile organic constituents. One set of field duplicates were collected and sent for the same analyses to determine field precision. All analyses were performed at Lancaster Laboratories, Lancaster, Pennsylvania, to prevent inter-laboratory variability.

3.0 WORKING GROUP TIER 1 RISK ASSESSMENT APPROACH

The first step in the Tier 1 assessment was the identification of contaminant sources, transport mechanisms, exposure pathways and potential receptors based on existing site information. Benzene was not detected in the soil sampled for this effort. In addition, the carcinogenic PAH indicators were not detected in sampling conducted by AmTech Engineering, Inc. Therefore, for purposes of establishing soil cleanup criteria, only noncarcinogenic risk was calculated. RBSLs were then calculated for each exposure pathway by applying the TPH fractionation results and the procedures established by the Working Group. The approach used for calculating TPH RBSLs differs from that used in a typical ASTM RBCA (1995) analysis in that it incorporates the concepts of additivity of risks (for the TPH mixture), chemical saturation concentrations (C_{sat}) and residual saturation (RES). Treating TPH as a mixture is especially important for consideration of fate, transport and toxicological interactions between individual chemicals or fractions.

Noncarcinogenic risk for each fraction is represented by the hazard quotient (HQ), which is the ratio of the estimated daily intake of a contaminant in given media (e.g., soil) to a reference dose (RfD) as follows:

$$HQ_i = \frac{\text{Intake Rate}(\text{mg}/\text{kg-day})}{RfD_i(\text{mg}/\text{kg-day})}$$

The intake rate depends upon the frequency and duration of exposure, as well as the source concentration and the transport rates between the source and the receptor for cross media pathways. Additivity is incorporated into the calculation of a "whole TPH" hazard index (HI) and RBSL by apportioning the total risk (i.e., HI = 1 for the mixture) over the different fractions present. That is, rather than each fraction assuming risk equal to a HQ of 1, each fraction would be allotted a portion of the risk, with the sum of the HQs from each fraction less than or equal to the HI of 1 for the mixture as depicted in the equation below.

$$HI = \sum_{i=1}^{i=n} HQ_i = \sum_{i=1}^{i=n} \frac{f_i C_{TPH}}{RBSL_i} \leq 1$$

where:

HI	=	Hazard Index (typically ≤ 1) [unitless]
n	=	Number of fractions (13 total)
HQ _i	=	Hazard Quotient for i th specific fraction [unitless]
f _i	=	Percent Weight of i th TPH fraction in "whole TPH" mixture [unitless]
C _{TPH}	=	TPH concentration in soil [mg/kg]
RBSL	=	Tier 1 risk-based screening level for a TPH fraction [mg/kg]

The assumption of additivity for calculating a TPH mixture RBSL is highly conservative because the toxicological information for the target fractions indicates that these fractions impact different organs (see Section 3.2). Typically, additivity is appropriate for constituents or constituent classes which impact the same organ.

For cross media pathways where transport, and therefore exposure, are maximized at the saturation concentration for specific fractions, the following equation is solved:

$$HI = \sum_{i=1}^{i=n} HQ_i = \text{Min} \left(\sum_{i=1}^{i=n} \frac{f_i C_{TPH}}{RBSL_i}, \sum_{i=1}^{i=n} \frac{C_{i sat}}{RBSL_i} \right) \leq 1 \quad \text{given,}$$

$$\sum_{i=1}^{i=13} f_i = \sum_{i=1}^{i=n} \frac{C_i}{C_{TPH}} = 1$$

where:

C _{i sat}	=	Saturation concentration for i th TPH fraction [mg/kg]
C _{TPH}	=	TPH Concentration [mg/kg]

C_{sat} serves as an upper exposure limit for cross media pathways. It represents the chemical concentration in soil at which the sorption limits of the soil particles, the solubility limits of the soil pore water and the saturation limit of the soil pore air have been reached. A concentration above the C_{sat} does not indicate the presence of mobile, free-phase chemicals. Actual mobility of a non-aqueous phase liquid (NAPL) depends on product and soil properties which are characterized by various capillary, gravitational, hydrodynamic and surface tension forces. However, at soil concentrations greater than C_{sat} , the likelihood of free phase NAPL should be considered. Once free product transfers, the assumptions of the Working Group approach are no longer valid and multi-phase transport should be considered. The calculation for C_{sat} is defined as:

$$C_{sat} \left[\frac{mg}{kg} \right] = \frac{S}{\rho_s} * [H_c \theta_{as} + \theta_{ws} + k_s \rho_s]$$

where:

S	=	Water Solubility [mg/L]
ρ_s	=	Soil Bulk Density [g/cm ³]
H_c	=	Henry's Law Constant [cm ³ /cm ³]
θ_{as}	=	Volumetric air content of the soil [cm ³ /cm ³]
θ_{ws}	=	Volumetric water content of the soil [cm ³ /cm ³]
k_s	=	Soil-water sorption coefficient ($k_s = K_{oc} * f_{oc}$) [cm ³ /g]

The C_{sat} limit does not apply to direct exposure pathways, such as the surface soil contact pathway. The exposure is to the original impacted media (e.g., contaminated soil) rather than to the cross media to which the contamination has been transferred.

A similar term which is sometimes confused with C_{sat} is residual saturation. When calculating an RBSL, a value of RES means that the selected risk level (e.g., HI = 1) could not be reached or exceeded for the pathway and scenario given the constituents present, regardless of the contaminant concentration. RES is obtained at the TPH concentration where the C_{sat} of the mixture is reached (i.e., each fraction has reached C_{sat}). When calculating a "whole TPH" RBSL, this means that even if the concentration of each fraction is set equal to C_{sat} for that fraction and pathway, the combined risk associated with each fraction still does not equal a HI of "1".

3.1 Physical Properties of the TPH Fractions

The 13 fractions in the Working Group approach were selected based on order of magnitude differences in partitioning properties. These properties are used in simple fate and transport models to evaluate the partitioning and migration of the TPH fractions for the different applicable pathways. This allows a more accurate estimation of exposure to the complex mixture than can be modeled from single TPH measurements.

Chemical properties which specifically govern how a chemical interacts with its environment include solubility, vapor pressure, sorption coefficient and Henry's Law Constant. In general, for any equivalent carbon number, the solubility of aromatic hydrocarbons is greater than that of aliphatic hydrocarbons; this is especially noticeable at high EC values. The variability in solubility around any given EC is about an order of magnitude. Aromatic hydrocarbons are

more likely to be present as dissolved constituents in groundwater than are the corresponding aliphatic hydrocarbons. There is very little difference in vapor pressure between aliphatic and aromatic constituents of an equivalent EC. In effect, the EC and vapor pressure are closely related.

The soil-water sorption coefficient (k_s) expresses the tendency of a chemical to be adsorbed onto a soil particle. In general, aliphatic fractions are more likely to remain bound to a soil particle than the aromatic fraction of an equivalent EC. Similarly, they exhibit low solubility.

Henry's Law Constant (H_c) is the ratio of a compound's concentration in air to its concentration in water at equilibrium. In general, aliphatic hydrocarbons are less soluble and more volatile than aromatic hydrocarbons. However, benzene is very volatile and more toxic than the corresponding aliphatic fractions. Therefore, when present, benzene is likely to drive risk calculations for pathways involving volatilization from soil or groundwater.

The physical properties of the 13 TPH fractions used to determine partitioning factors are provided in Table 3-1. The equations used to develop these fate and transport properties are available in the Working Group's Volume 3 (TPHCWG, 1998b).

TABLE 3-1 TPH FRACTIONS DERIVED FROM FATE AND TRANSPORT CHARACTERISTICS AND ASSOCIATED PROPERTIES¹

	Solubility (mg/L)	Henry's Constant	Molecular Weight (g/mol)	Vapor Pressure (atm)	$\log K_{oc}$ ² (cm ³ /cm ³)	PF ³ (soil/water)	PF ³ (soil/vapor)
Aliphatics							
EC5-EC6	3.6E+01	3.4E+01	8.1E+02	3.5E-01	2.9E+00	1E+01	3E-01
>EC6-EC8	5.4E+00	5.1E+01	1.0E+02	6.3E-02	3.6E+00	4E+01	9E-01
>EC8-EC10	4.3E-01	8.2E+01	1.3E+02	6.3E-03	4.5E+00	3E+02	6E+00
>EC10-EC12	3.4E-02	1.3E+02	1.6E+02	6.3E-04	5.4E+00	3E+03	5E+01
>EC12-EC16	7.6E-04	5.4E+02	2.0E+02	4.8E-05	6.7E+00	7E+04	1E+03
>EC16-EC35	1.3E-06	6.4E+03	2.7E+02	7.6E-06	9.0E+00	1E+07	1E+05
Aromatics							
EC6-EC7	1.8E+03	2.3E-01	7.8E+01	1.3E-01	1.9E+00	9E-01	4E+00
>EC7-EC8	5.2E+02	2.7E-01	9.2E+01	3.8E-02	2.4E+00	2E+00	9E+00
>EC8-EC10	6.5E+01	4.9E-01	1.2E+02	6.3E-03	3.2E+00	2E+01	5E+01
>EC10-EC12	2.5E+01	1.4E-01	1.3E+02	6.3E-04	3.4E+00	2E+01	2E+02
>EC12-EC16	5.8E+00	5.4E-02	1.5E+02	4.8E-05	3.7E+00	5E+01	2E+03
>EC16-EC21	5.1E-01	1.3E-02	1.9E+02	7.6E-06	4.2E+00	1E+02	4E+04
>EC21-EC35	6.6E-03	6.8E-04	2.4E+02	4.4E-09	5.1E+00	1E+03	3E+07

Notes: Table extracted in part from TPHCWG, 1998b.

¹ Based on an equivalent carbon number, which is proportional to normal boiling point

² K_{oc} = organic carbon sorption coefficient

³ PF – partition factors for soil to water and soil to vapor concentrations at equilibrium

Values based on pure compounds. Behavior may differ in complex mixtures.

3.2 Overview of Toxicity Criteria for Fate and Transport Fractions

The Working Group approach focuses on both carcinogenic and non-carcinogenic impacts to human health. In order to assess carcinogenic risk, indicator compounds are used (benzene and the carcinogenic PAHs). The assessment of non-carcinogenic risk uses the fraction-specific toxicity criteria summarized in Table 3-2. The majority of constituents in TPH are noncarcinogenic.

TABLE 3-2 WORKING GROUP TOXICOLOGY FRACTION-SPECIFIC RfDs

Effective Carbon Range	Aromatic RfD (mg/kg/day)	Critical Effect	Aliphatic RfD (mg/kg/day)	Critical Effect
EC5-EC6 EC7-EC8	0.20 - Oral 0.10 - Inhalation	Hepatotoxicity, Nephrotoxicity	5.0 - Oral 5.0 - Inhalation	Neurotoxicity
EC9-EC10 EC11-EC12 EC13-EC16	0.04 - Oral 0.05 - Inhalation	Decreased body weight	0.1 - Oral 0.3 - Inhalation	Hepatic and hematological changes
EC17-EC21 EC22-EC34	0.03	Decreased body weight	1.00	Hepatic granuloma (foreign body reaction)
>EC34	—	—	20 - Oral	Hepatic changes

RfDs are estimates of daily exposure to the human population, including sensitive subgroups, that are likely to be without appreciable risk of deleterious effects during a lifetime. RfDs are developed for non-carcinogenic compounds. In some cases, the same toxicity criterion is assigned to different fate and transport fractions due to the similarity of toxicity findings across fractions or limitations in the available toxicity data. Yet, the fractions are assessed separately so that the exposure potential of each fraction may be estimated appropriately. Combining fate and transport information with the RfDs for each fraction, fraction-specific RBSLs are estimated for each applicable exposure scenario. These fraction-specific RBSLs are then combined with a site-specific mixture composition to calculate a single mixture-specific TPH RBSL.

If carcinogenic indicators are present, they must be evaluated separately since they often drive cleanup even in relatively low concentrations. The hazard assessment for TPH fractions would only be used in cases where indicator compounds are not present or are present below regulatory action levels. More information on the development of the RfDs is provided in the Working Group's Volume 4 (TPHCWG, 1998c).

In general, aromatic fractions have lower RfDs than aliphatic fractions and are approximately an order of magnitude more toxic than the corresponding aliphatic fraction. These values are based on chronic effects which include hepatotoxicity (liver toxicity), nephrotoxicity (kidney toxicity) and decreased body weight.

4.0 ANALYTICAL RESULTS

All of the samples collected for the demonstration were taken from within areas on the excavation walls that exhibited staining, at approximately eight to nine ft bgs. PID readings from the excavation walls were taken by AmTech Engineering, Inc. one week prior to this sampling effort and provided as a guide. These readings ranged from 2 to 800 ppm; however the location of the highest PID readings during this sampling effort did not match the locations noted the previous week. The later readings were very low, ranging from 9 to 400 ppm. Analytical results and the chain of custody forms are provided in Appendix A.

4.1 Direct Method Results

The aromatic and aliphatic fraction distributions for the Field Demonstration soils generated using the Direct Method are provided in Table 4-1. Of the eight samples analyzed, only two samples (E45S8-1 and E85S8-2) resulted in detectable levels across the fractions. A few samples resulted in detectable concentrations in the aliphatics EC6 to EC8 and EC10 to EC12 ranges; however, these levels were just above limits of quantitation.

TABLE 4-1 DIRECT METHOD ANALYTICAL RESULTS

Laboratory ID:	2924948	2924949	2924950	2924951	2924953
Sample ID:	E45S8-1	E85S8-2	E105S8-3	E135SE9-4	E85N8-6
5-6 Aliphatics	ND <10.3	ND <5.2	ND <10.4	ND <5.0	ND <10.3
5-7 Aromatics (Benzene)	ND <0.3	ND <0.1	ND <0.3	ND <0.1	ND <0.3
>6-8 Aliphatics	15.7	ND <5.2	14.6	6.5	11.3
>6-8 Aromatics (Toluene)	ND <0.3	ND <0.1	ND <0.3	ND <0.1	ND <0.3
>8-10 Aliphatics	123.3	35.8	ND <10.4	ND <10.0	12.1
>8-10 Aromatics	ND <10.3	ND <10.4	ND <10.4	ND <10.0	ND <10.3
>10-12 Aliphatics	182.6	74.0	11.3	17.4	17.8
>10-12 Aromatics	32.3	ND <10.4	ND <10.4	ND <10.0	ND <10.3
>12-16 Aliphatics	130.8	57.3	ND <25.9	ND <25.1	ND <25.6
>12-16 Aromatics	45.7	ND <25.9	ND <25.9	ND <25.1	ND <25.6
>16-21 Aliphatics	ND <25.8	ND <25.9	ND <25.9	ND <25.1	ND <25.6
>16-21 Aromatics	ND <25.8	ND <25.9	ND <25.9	ND <25.1	ND <25.6
>21-35 Aliphatics	ND <64.4	ND <64.8	ND <64.8	ND <62.7	ND <64.1
>21-35 Aromatics	ND <64.4	ND <64.8	ND <64.8	ND <62.7	ND <64.1
Total Aliphatics	462	210	ND <155	ND <138	ND <154
Total Aromatics	136	<130	ND <130	ND <125	ND <128
Total "TPH"	598	281	ND	ND	ND

Notes: Units: mg/kg dry weight

"<" indicates true value is less than limit of quantitation (LOQ) value presented.

Bolded values indicate detected quantities.

Totals do not necessarily reflect the arithmetic sum of the detected fraction values because NDs are not necessarily zeros and contribute to the area under the chromatogram curve yielding the total values.

The quantitation limits are somewhat conservative. The reporting limits may be lower for this method if most of the petroleum hydrocarbons present in a given fraction are from just a few GC peaks. The Direct Method remains under development and refinements are anticipated.

The fraction profiles of the samples with detectable concentrations are presented in Figure 4-1. The TPH present is comprised primarily of aliphatic compounds within the EC8 to EC16 range. More specifically, approximately 13 to 21% of the aliphatic hydrocarbons are in the EC8 to EC16 range, 26 to 31% in the EC10 to EC12 range and 20 to 22% in the EC12 to EC16 range. A small percentage of the TPH (i.e., 0 to 8%) was detected in the aromatic EC12 to EC16 range. The most likely composition of the samples includes cyclic alkanes, branched alkanes and substituted aromatics, based on GC/MS analysis. Evaporative weathering was demonstrated by the lack of light hydrocarbons present. Biodegradation was observed, as indicated by the loss of n-alkanes. Highly branched alkanes predominated. These compounds are generally resistant to biodegradation and compose the majority of JP-8. Fresh JP-8, a middle distillate, has very low levels of BTEX and PAHs.

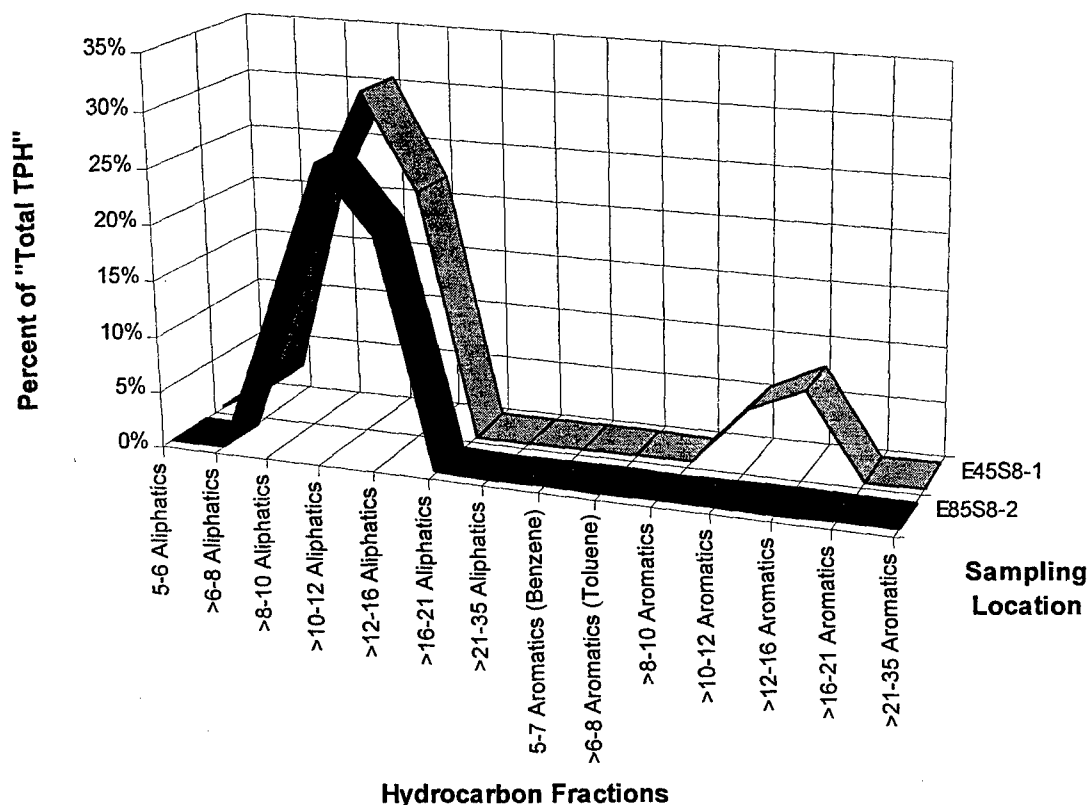


Figure 4-1 Fraction Composition: Direct Method

4.2 Comparison of Conventional Method and Direct Method Results

A comparison of results obtained using the fractionation method and the conventional method is presented in Table 4-2. TPH concentrations ranged from approximately ND to 598 mg/kg for

samples analyzed by the Direct Method, and ND to 1,710 mg/kg for samples analyzed by EPA Method 8015B for DRO and API Method for GRO. The conventional method consistently provided higher estimates of the TPH present. This trend has also been noted in other field demonstrations.

TABLE 4-2 SUMMARY OF COMPARATIVE TPH DATA

Sample ID	Laboratory ID	TPH-GRO API	TPH-DRO by 8015B (EC10-28)	Total GRO+DRO	Direct Method
E45-S-8-1	2924948	310	1,400	1,710	598
E85-S-8-2	2924949	180	320	500	281
E105-S-8-3	2924950	160	130	290	ND <130
E135-SE-9-4	2924951	80	130	210	ND <125
E135-NE-9-5	2924952	60	93	153	ND <128
E85-N-8-6	2924953	100	200	300	ND <128
E45-N-8-7	2924954	<50	140	140	ND <125
E30-NW-7-8	2924955	<1.0	ND <9	ND <1	ND <129
E225-B-2-9	2924956	<1.0	18	18	ND <128

Note: Units: mg/kg dry weight

"<" indicates true value is less than LOQ value presented.

Both the API DRO and the Direct Method are GC analyses. The API method measures hydrocarbons up to EC28. The Direct Method determines hydrocarbons up to EC35. Therefore, one would expect a more complete analysis of the TPH mixture and typically a higher concentration reported by the Direct Method. The higher values reported by the API method in this study may be attributed to a more efficient extraction process (the use of methylene chloride versus *n*-pentane). The soil sampled was a very tight silty clay with high moisture content, not easily broken up and homogenized. The analytical laboratory also reported that it was difficult to obtain a homogeneous aliquot from the samples. This may account for the large differences reported between the different analyses run on the same samples. As JP-8 is a middle distillate, it spans both the GRO and DRO ranges; Method 8015B DRO and API method for GRO combined may result in some overlap and overestimation of TPH concentrations.

4.3 BTEX Results

The summary of BTEX analyses for the nine samples analyzed (a background sample was included) are shown in Table 4-3. Benzene, toluene and the xylene isomers were not detected in any of the soil samples analyzed. Ethylbenzene was detected in parts per million concentrations in a few samples, but no sample exceeded the Illinois TACO Tier 1 level of 13 mg/kg for ethylbenzene under a residential land use scenario. While benzene was not detected in any of the samples, the LOQs reported for benzene on most of the samples were higher than the TACO Tier 1 value for residential use (0.03 mg/kg).

TABLE 4-3 SUMMARY OF BTEX RESULTS BY SW-846 8021A

Sample ID	Benzene	Toluene	Ethylbenzene	Xylenes (total)
E45-S-8-1	ND <0.26	ND <0.26	1.5	ND <3.2
E85-S-8-2	ND <0.13	ND <0.13	0.95	ND <1.3
E105-S-8-3	ND <0.26	ND <0.26	1.0	ND <1.3
E135-SE-9-4	ND <0.13	ND <0.13	0.37	ND <1.3
E135-NE-9-5	ND <0.64	ND <0.64	ND <0.31	ND <0.64
E85-N-8-6	ND <0.26	ND <0.26	0.57	ND <0.77
E45-N-8-7	ND <0.26	ND <0.26	0.32	ND <0.78
E30-NW-7-8	ND <0.0064	ND <0.0064	ND <0.0064	ND <0.019
E225-B-2-9	ND <0.006	ND <0.006	ND <0.006	ND <0.018

Notes: Units: mg/kg

"<" indicates true value is less than LOQ value presented.

Bolded values indicate detected quantities.

Due to interference from the sample matrix, the LOQs for the above determinations were increased.

4.4 Quality Control Results

Analytical results of the field duplicates and the matrix spike analyses performed on a background sample are provided in Appendix A. Field duplicates were both nondetects. The background sample was spiked with analytes from the specific Working Group hydrocarbon fractions from >EC8 to <EC35 and analyzed with procedures identical to those used for the site samples. Recoveries ranged from 60.9% to 96.2%.

4.5 Analytical Results Summary

The sources of contamination at Site 508 were identified as the underground storage tanks 286 and 287, which contained JP-8 before their removal. Based on the samples collected, the contamination does not extend much beyond the walls of the excavation. None of the soil samples exceeded Illinois TACO Tier 1 levels for BTEX (0.03/12/13/190 mg/kg for B/T/E/X, respectively); however quantitation limits reported for BTEX were higher than this criteria. TPH concentrations around the site were very low, even around the former location of the tank piping.

Generally, the conventional method consistently provided higher estimates of the TPH present than the fractionation method. A correlation between the methods could not be drawn based on two samples. The other samples resulted in nondetectable levels from the Direct Method analysis and low levels from EPA Method 8015B. The Direct Method may be more accurate and provide more information regarding the constituents present; however, at present, it is not highly effective for measuring TPH concentrations less than approximately 200 mg/kg.

5.0 RISK-BASED SCREENING LEVELS

For the purposes of the field demonstration, the RBCA analysis conducted using the Working Group approach was based upon a site conceptual model which assumes leaching from subsurface soil to groundwater and vapor transport to outdoor and indoor air. The area surrounding the impacted site is agricultural. Currently, the nearest drinking water well is located approximately 1,700 feet southwest of the site. Both residential and commercial dwellings are located on the base, but not immediately above the impacted site. The impacted area will remain industrial as part of the Base for the foreseeable future; however, future land use does not exclude either residential or commercial use.

Therefore, for the Tier 1 assessment, the location of actual receptors was modified to expand the number of pathways which could be evaluated. It was assumed that a residential housing development with a potable well could be located on site immediately above impacted subsurface soils. The direct contact with soil pathway was also considered, based on the assumption that individuals could come into contact with impacted subsurface soils during agricultural use or during a construction/industrial scenario.

The soil leaching to groundwater pathway was evaluated for purposes of demonstration, as it is common at TPH sites. Vaporization pathways from impacted soils to outdoor and indoor air were also evaluated. Use of the volatilization to indoor air pathway is an extremely conservative assumption because buildings are not located above or directly adjacent to the impacted area and it does not currently represent a potential pathway. A RBCA site assessment diagram identifying sources, pathways and receptors is provided in Figure 5-1. Exposure pathways evaluated include:

- Soil leaching to groundwater and ingestion of groundwater
- Volatilization from subsurface soils to indoor air
- Volatilization from subsurface soils to outdoor air
- Direct contact with soils

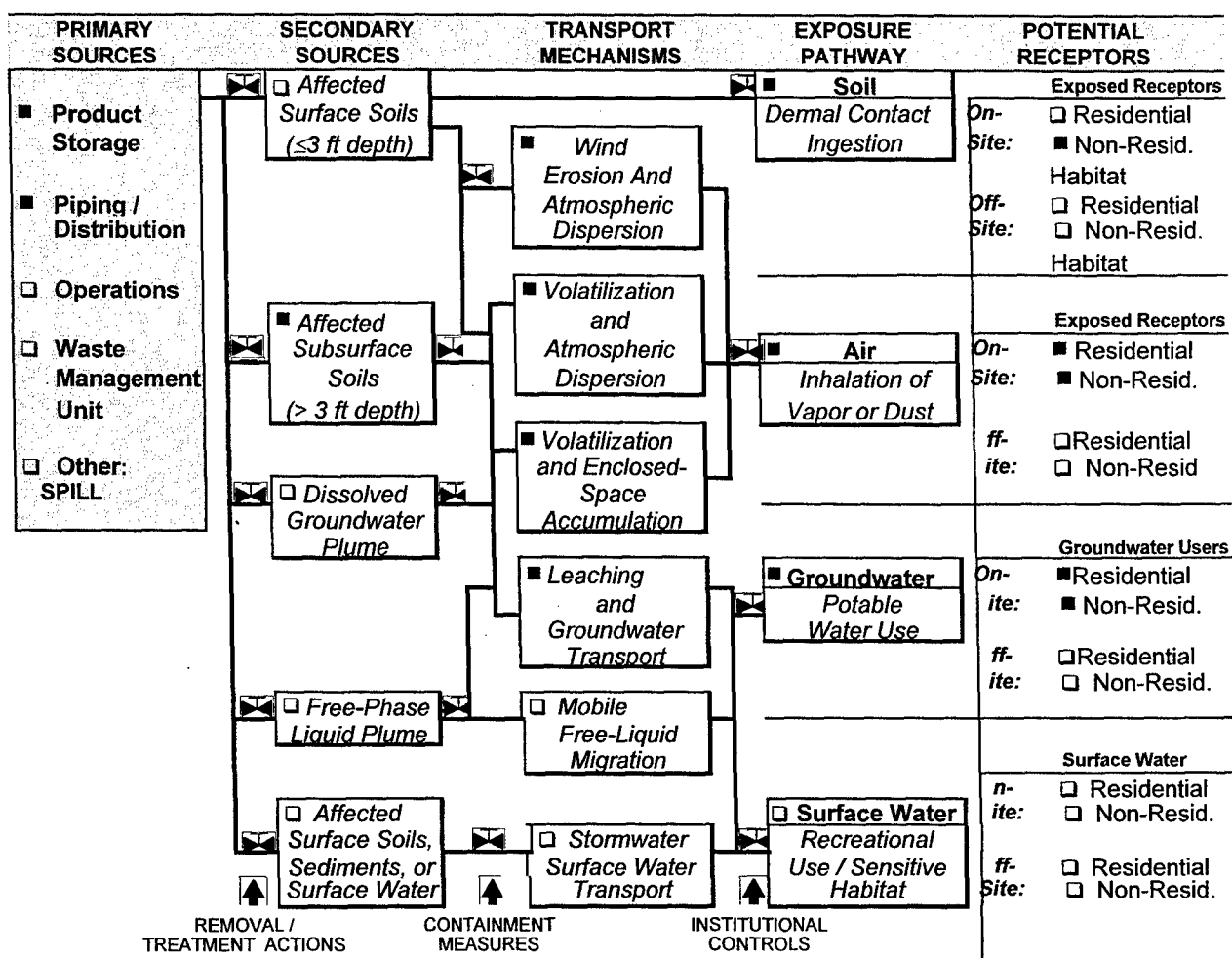


Figure 5-1 Exposure Pathway Analysis

The results of Tier 1 evaluations are presented in the following sections as a RBSL and a pathway-specific HI for each soil sample and pathway evaluated. A detailed discussion on the development of RBSLs is presented in Appendix B. The risk results and RBSLs from the model runs are provided in Appendix C. For comparison purposes, RBSLs were developed first using one-half the detection limit for fractions with nondetects and again using zero for nondetects. RBSLs represent soil concentrations which would not result in unacceptable risk levels. The HI represents a comparison between the TPH concentration and the RBSL as follows:

$$\text{HazardIndex (HI)} = \frac{\text{TPH concentration (mg / kg)}}{\text{RBSL}_{\text{pathway}} \text{ (mg / kg)}}$$

5.1 Residential Scenario Risk Results

Residential scenario Tier 1 RBSLs and HIs for the fractionated samples are presented in Tables 5-1a and b. The RBSLs presented in Table 5-1a were developed using one-half the detection

limit for nondetects, whereas the RBSLs in Table 5-1b were developed using zero for nondetects. Typically, one-half the detection limit is used to represent nondetects when establishing exposure concentrations. Using this approach in the Tier 1 assessment, RBSLs for the soil leaching pathway ranged from approximately 4,202 to 5943 mg/kg. The volatilization to outdoor air pathway resulted in RBSLs exceeding 362,000 mg/kg. RBSLs for the direct contact pathway ranged from 5024 to 6112 mg/kg. Indoor air RBSLs were indeed the most restrictive, ranging from 115 to 158 mg/kg. The target risk level (hazard index) of 1.0 was only exceeded for the volatilization to indoor air pathway. It should be noted, however, that the indoor air pathway is an incomplete route of exposure because no buildings are located above or immediately adjacent to the site. Therefore, eliminating this pathway is valid. However, as stated earlier, the indoor air pathway was presented for the purpose of demonstration. Additionally, the model for volatilization to indoor air is recognized as overly and unnecessarily conservative by EPA, as the default value for the fracture size of the foundation drives the risk.

**TABLE 5-1a TIER 1 RESIDENTIAL SOIL RBSLs AND HIs
USING ONE-HALF THE LOQ FOR NONDETECTS¹**

Sample #	TPH Present (mg/kg)	Soil Leaching to Groundwater		Volatilization to Outdoor Air		Volatilization to Indoor Air		Direct Contact	
		RBSL (mg/kg)	HI	RBSL (mg/kg)	HI	RBSL (mg/kg)	HI	RBSL (mg/kg)	HI
E45S8-1	598	4208	0.14	401829	NA	115	5.18	6112	0.10
E85S8-2	281	5943	0.05	362984	NA	158	1.78	5924	0.05
Average	440	5076	0.09	382407	NA	137	3.22	6018	0.07

Notes: NA = not applicable, either HI is insignificant or pathway is incomplete.

¹ The fraction-specific RBSLs used to establish "whole TPH" RBSLs were calculated using one-half the LOQ for fractions below detection limits.

**TABLE 5-1b TIER 1 RESIDENTIAL SOIL RBSLs AND HIs
USING ZERO FOR NONDETECTS¹**

Sample Number	TPH Present (mg/kg)	Soil Leaching to Groundwater		Volatilization to Outdoor Air		Volatilization to Indoor Air		Direct Contact	
		RBSL (mg/kg)	HI	RBSL (mg/kg)	HI	RBSL (mg/kg)	HI	RBSL (mg/kg)	HI
E45S8-1	598	4831	0.12	200915	NA	101	5.91	6432	0.09
E85S8-2	281	2972	0.09	181492	NA	105	2.68	7783	0.04
Average	440	3901	0.11	191203	NA	103	4.29	7107	0.06

Notes: NA = not applicable, either HI is insignificant or pathway is incomplete.

¹ The fraction-specific RBSLs used to establish "whole TPH" RBSLs were calculated using zero for fractions below detection limits.

In general, the RBSLs developed using zero for nondetects (Table 5-1b) were higher than those developed using one-half the detection limit with the exception of the volatilization to indoor air RBSLs. This is because a greater percentage of the "whole TPH" is assumed to be attributed to the volatile aliphatic EC8 through EC10 and EC10 through EC12 ranges (i.e., the volatile fractions detected) by using this approach. By using half the detection limit, the proportion of

risk attributed to each of the 13 fractions is more evenly distributed. Therefore, nonvolatile heavier fractions, which are also lower in toxicity, are attributed a significant portion of the risk. It should also be noted that the model used to develop indoor air concentrations is highly conservative, assuming steady state diffusion, no attenuation and complete migration. Improvements to reduce the uncertainty of the indoor air model are currently being evaluated.

5.2 Commercial Scenario Risk Results

Tables 5-2a and b present the Tier 1 RBSLs for the commercial scenario, developed using one-half the detection limit and zero for fractions reported as nondetect, respectively. Using one-half the detection limit, RBSLs for the soil leaching pathway ranged from approximately 22,000 to 30,000 mg/kg. RBSLs for the direct contact pathway ranged from 8765 to 9036 mg/kg. The volatilization to outdoor air pathway resulted in RBSLs exceeded 100% for all fractionated samples. Again the indoor air pathway represented the most conservative RBSLs (303 mg/kg). The volatilization to indoor air pathway is currently not complete at the site; however, it should be evaluated as to its real potential as a future pathway. If the future use of the site includes paving for commercial development as an air strip, this pathway should be eliminated. This was the only pathway exceeding a HI of 1.0.

**TABLE 5-2a TIER 1 COMMERCIAL SOIL RBSLs AND HIs
USING ONE-HALF THE LOQ FOR NONDETECTS¹**

Sample Number	TPH Present (mg/kg)	Soil Leaching to Groundwater		Volatilization to Outdoor Air		Volatilization to Indoor Air		Direct Contact	
		RBSL (mg/kg)	HI	RBSL (mg/kg)	HI	RBSL (mg/kg)	HI	RBSL (mg/kg)	HI
E45S8-1	598	30796	0.02	1282137	NA	303	1.97	9036	0.07
E85S8-2	281	22243	0.01	1158194	NA	448	0.63	8765	0.03
Average	440	26519	0.02	1220165	NA	376	1.17	8901	0.05

Notes: NA = not applicable, either HI is insignificant or pathway is incomplete.

¹ The fraction-specific RBSLs used to establish "whole TPH" RBSLs were calculated using one-half the limit of quantification for fractions below detection limits.

**TABLE 5-2b TIER 1 COMMERCIAL SOIL RBSLs and HIs
USING ZERO FOR NONDETECTS¹**

Sample Number	TPH Present (mg/kg)	Soil Leaching to Groundwater		Volatilization to Outdoor Air		Volatilization to Indoor Air		Direct Contact	
		RBSL (mg/kg)	HI	RBSL (mg/kg)	HI	RBSL (mg/kg)	HI	RBSL (mg/kg)	HI
E45S8-1	598	15398	0.04	641069	NA	270	2.22	9503	0.06
E85S8-2	281	11121	0.03	579097	NA	316	0.89	11510	0.02
Average	440	13260	0.03	610083	NA	293	1.55	10507	0.04

Notes: NA = not applicable, either HI is insignificant or pathway is incomplete.

¹ The fraction-specific RBSLs used to establish "whole TPH" RBSLs were calculated using zero for fractions below detection limits.

The RBSLs using one-half the LOQ (Table 5-2b) were generally higher than those developed using zeros for nondetectable fractions. For the soil leaching to groundwater and the volatilization to outdoor air the difference is approximately a factor of two. One might expect the opposite effect; however, by using one-half the LOQ. The proportion of TPH was more evenly spread across all fractions, including the least mobile and least toxic fractions (EC12 and greater) of the mixture.

5.3 Risk Discussion

Only two samples reported detectable TPH levels useful for the development of RBSLs. The Working Group approach, however, provided conservative yet meaningful RBSLs which could be applied at this site. The highest concentrations reported from both the fractionation and GRO/DRO results (598 and 1,710 mg/kg, respectively) did not exceed the RBSLs for all pathways, with the exception of the indoor air RBSLs (115 to 448 mg/kg). This pathway was evaluated as a potential future pathway for demonstration; however currently it is not complete and should not be used for establishing cleanup. The most restrictive RBSL for the other pathways evaluated (using one-half the LOQ for nondetects) was 3924 mg/kg for the residential direct contact pathway. None of the samples exceeded this RBSLs. Therefore, based on potential pathways and the TPH fractions present in these samples, risks are at acceptable levels. Closure of the site is recommended.

5.4 Comparison with Illinois Regulatory Guidance

The guidelines for determining risk-based, site-specific cleanup objectives are given in the state's Tiered Approach to Corrective Action Objectives (Illinois EPA, 1997). The first step is comparison of sampling results to TACO tier-one "look-up" tables that show the strictest cleanup levels for all potential contaminants. If the levels exceed the values listed in the tables, the land/site owner can either delineate the area of concern or move on to a tier-two analysis. Tier-two involves calculating the human health risk for the levels of contaminants of concern. Tier-three, an even more sophisticated analysis, takes site-specific options into account. The number of tiers of analysis an owner uses thus depends both on the complexity of the environmental concerns and the cost of obtaining various levels of information about the site.

Although the Illinois TACO develops RBSLs for BTEX and PAHs, whereas the Working Group approach develops one TPH RBSL based on the TPH fractions present, the two assessments are somewhat comparable. Both use the tiered approach, as described above. BTEX and PAHs are included in the fractionation analytical results and all are assessed, with the exception of carcinogenic indicators benzene and PAHs. If these indicator compounds are present, the Working Group approach assesses them separately. Analytical costs may actually be lower using the Working Group approach. If the TPH profiles are similar across the site, conventional analysis may be used to characterize the extent of contamination. Only a few analyses using the Direct Method are necessary for developing RBSLs. This could result in cost savings over running analyses for BTEX and PAHs on each sample.

In this case, benzene and carcinogenic PAHs were not detected in soil (based on the soil samples collected for this effort and information provided by AmTech Engineering). Therefore,

the use of the Working Group approach is very applicable at such a site. However, the approach would be more applicable for a similar site with higher concentrations, given the Direct Method appears less effective for reporting concentrations below approximately 200 mg/kg "whole" TPH.

RBSLs for the soil leaching to groundwater, volatilization to outdoor air and the direct contact pathway were not exceeded. The indoor air RBSLs were exceeded, but this pathway was not currently complete. The evaluation of these pathways was included for demonstration purposes since they are common pathways at TPH sites.

6.0 CONCLUSIONS

This exercise indicated that the Working Group approach provides cleanup criteria that is scientifically defensible. Implementing the Working Group approach may increase the initial costs of characterizing a clean-up activity due to the need for additional and more costly analyses. However, in a state like Illinois where each sample is analyzed for BTEX and PAHs, analytical costs may actually be lower using the Working Group approach. If the TPH profiles are similar across the site, conventional analysis may be used to characterize the extent of contamination. Only a few analyses using the Direct Method are necessary for developing RBSLs. In addition remediation costs may be significantly reduced because clean-up levels may be higher, yet they are human health risk-based. The Working Group approach also provides a much better understanding of the remaining constituents in a complex weathered mixture.

The highest TPH concentration reported from the GRO + DRO analyses was nearly three times higher than it's corresponding concentration reported from Direct Method analysis. The next highest concentration, however, was 0.56 times higher from the GRO + DRO analyses than from the Direct Method. Unfortunately for demonstration purposes, the levels at this site were extremely low. Most samples yielded TPH concentrations below detection limits for the Direct Method and could not be used in developing a meaningful correlation. A well conducted study to analyze the variance between the Direct Method and conventional methods, taking into consideration levels of contamination, carbon number distribution and soil parameters, is warranted.

7.0 REFERENCES

American Society for Testing and Materials (ASTM), 1995. "Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites, E 1739-95".

AmTech Engineering, Inc. Jan. 1998. 45-Day Report: Leaking Underground Storage Tank, Incident #972284. Building 508, Tanks 8620 and 8621, Scott AFB. Prepared for Headquarters, 375th Airlift Wing (AMC).

Environmental Resources Management, Inc. April 1992. Installation Restoration Program Stage 1 Remedial Investigation/Feasibility Study, Scott AFB. Final Technical Report Vol. I. Prepared for Headquarters Military Airlift Command.

Illinois EPA. July, 1997. Title 35 of the Illinois Administrative Code. Environmental Protection. Subtitle G: Waste Disposal, Chapter I: Pollution Control Board, Subchapter f: Risk Based Cleanup Objectives. Part 742 Tiered Approach to Corrective Action Objectives.

TPHCWG. 1998a. A Risk-based Approach for the Management of Total Petroleum Hydrocarbons in Soil, Volume 1: Petroleum Hydrocarbon Analysis of Soil and Water in the Environment.

TPHCWG. 1998b. A Risk-based Approach for the Management of Total Petroleum Hydrocarbons in Soil, Volume 3. Selection of TPH Fractions Based on Fate and Transport Considerations.

TPHCWG. 1998c. A Risk-based Approach for the Management of Total Petroleum Hydrocarbons in Soil, Volume 4: Development of Fraction Specific Reference Doses (RfDs) and Reference Concentrations (RfCs) for Total Petroleum Hydrocarbons (TPH).

HYDROCARBON SPECIATION PROJECT

C8 to C35 Hydrocarbons by Purge & Trap GC PID/FID
C5 to C8 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Extractable Batch ID: 981320002A

Laboratory ID: 2924948

Sample ID: E4581

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	8	ND	0.2	ND	NA
VRH 2 **	NA	NA	12.2	8	ND	0.2	12.2	NA
>C8 - <=C10	126.4	8	95.7	8	ND	8	102.3	81%
>C10 - <=C12	193.6	8	141.7	8	25.1	8	166.7	86%
>C12 - <=C16	160	20	102	20	35	20	137	86%
>C16 - <=C21	ND	20	ND	20	ND	20	ND	NA
>C21 - <=C35	ND	50	ND	50	ND	50	ND	NA
Total >C8 - <=C35	495	100	346	100	105	100	451	91%
Total >C5 - <=C35	NA	NA	359	120	105	100	464	NA

% moisture = 22.4

C5 to C35 Hydrocarbons "Dry Weight Data"

Laboratory ID: 2924948

Sample ID: E4581

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	10	ND	0.3	ND	NA
VRH 2 **	NA	NA	15.7	10	ND	0.3	15.8	NA
>C8 - <=C10	162.9	10	123.3	10	ND	10	131.8	81%
>C10 - <=C12	249.5	10	182.6	10	32.3	10	214.9	86%
>C12 - <=C16	206	26	131	26	46	26	176	86%
>C16 - <=C21	ND	26	ND	26	ND	26	ND	NA
>C21 - <=C35	ND	64	ND	64	ND	64	ND	NA
Total >C8 - <=C35	637	129	445	129	135	129	581	91%
Total >C5 - <=C35	NA	NA	462	155	136	129	598	NA

* Volatile Range Hydrocarbons (Range 1 Aliphatics = C5 to C6 aliphatic (total) hydrocarbons
Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)
** Volatile Range Hydrocarbons (Range 2 Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)
Aromatics = >C7 to C8 aromatics (toluene only)

Prepared by Delwyn K Schumacher

HYDROCARBON SPECIATION PROJECT

C8 to C35 Hydrocarbons by Purge & Trap GC PID/FID
C5 to C8 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Extractable Batch ID: 981320002A

Laboratory ID: 2924949

Sample ID: E8582

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	4	ND	0.1	ND	NA
VRH 2 **	NA	NA	ND	4	ND	0.1	ND	NA
>C8 - <=C10	41.1	8	27.6	8	ND	8	29.1	71%
>C10 - <=C12	83.7	8	57.1	8	ND	8	63.0	75%
>C12 - <=C16	70	20	44	20	ND	20	60	85%
>C16 - <=C21	ND	20	ND	20	ND	20	ND	NA
>C21 - <=C35	ND	50	ND	50	ND	50	ND	NA
Total >C8 - <=C35	200	100	158	100	ND	100	212	106%
Total >C5 - <=C35	NA	NA	162	110	ND	100	217	NA

% moisture = 22.8

C5 to C35 Hydrocarbons "Dry Weight Data"

Laboratory ID: 2924949

Sample ID: E8582

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	5	ND	0.1	ND	NA
VRH 2 **	NA	NA	ND	5	ND	0.1	ND	NA
>C8 - <=C10	53.3	10	35.8	10	ND	10	37.8	71%
>C10 - <=C12	108.4	10	74.0	10	ND	10	81.6	75%
>C12 - <=C16	91	26	57	26	ND	26	77	85%
>C16 - <=C21	ND	26	ND	26	ND	26	ND	NA
>C21 - <=C35	ND	65	ND	65	ND	65	ND	NA
Total >C8 - <=C35	259	130	204	130	ND	130	275	106%
Total >C5 - <=C35	NA	NA	210	142	ND	130	281	NA

* Volatile Range Hydrocarbons (Range 1 Aliphatics = C5 to C6 aliphatic (total) hydrocarbons

Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2 Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)

Aromatics = >C7 to C8 aromatics (toluene only)

Prepared by Delwyn K Schumacher

HYDROCARBON SPECIATION PROJECT

C8 to C35 Hydrocarbons by Purge & Trap GC PID/FID
C5 to C8 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Extractable Batch ID: 981320002A

Laboratory ID: 2924950

Sample ID: 10583

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	8	ND	0.20	ND	NA
VRH 2 **	NA	NA	11.3	8	ND	0.20	11.4	NA
>C8 - <=C10	ND	8	ND	8	ND	8	ND	NA
>C10 - <=C12	10.8	8	8.7	8	ND	8	11.1	102%
>C12 - <=C16	ND	20	ND	20	ND	20	ND	NA
>C16 - <=C21	ND	20	ND	20	ND	20	ND	NA
>C21 - <=C35	ND	50	ND	50	ND	50	ND	NA
Total >C8 - <=C35	ND	100	ND	100	ND	100	ND	NA
Total >C5 - <=C35	NA	NA	ND	120	ND	100	ND	NA

% moisture = 22.8

C5 to C35 Hydrocarbons "Dry Weight Data"

Laboratory ID: 2924950

Sample ID: 10583

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	10	ND	0.26	ND	NA
VRH 2 **	NA	NA	14.6	10	ND	0.26	14.8	NA
>C8 - <=C10	ND	10	ND	10	ND	10	ND	NA
>C10 - <=C12	14.0	10	11.3	10	ND	10	14.3	102%
>C12 - <=C16	ND	26	ND	26	ND	26	ND	NA
>C16 - <=C21	ND	26	ND	26	ND	26	ND	NA
>C21 - <=C35	ND	65	ND	65	ND	65	ND	NA
Total >C8 - <=C35	ND	130	ND	130	ND	130	ND	NA
Total >C5 - <=C35	NA	NA	ND	155	ND	130	ND	NA

* Volatile Range Hydrocarbons (Range 1 Aliphatics = C5 to C6 aliphatic (total) hydrocarbons
Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2 Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)
Aromatics = >C7 to C8 aromatics (toluene only)

Prepared by Delwyn K Schumacher

HYDROCARBON SPECIATION PROJECT

C8 to C35 Hydrocarbons by Purge & Trap GC PID/FID
C5 to C8 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Extratable Batch ID: 981320002A

Laboratory ID: 2924951

Sample ID: 13594

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	4	ND	0.1	ND	NA
VRH 2 **	NA	NA	5.2	4	ND	0.1	5.2	NA
>C8 - <=C10	ND	8	ND	8	ND	8	ND	NA
>C10 - <=C12	20.0	8	13.8	8	ND	8	16.3	82%
>C12 - <=C16	25	20	ND	20	ND	20	ND	NA
>C16 - <=C21	ND	20	ND	20	ND	20	ND	NA
>C21 - <=C35	ND	50	ND	50	ND	50	ND	NA
Total >C8 - <=C35	ND	100	ND	100	ND	100	ND	NA
Total >C5 - <=C35	NA	NA	ND	110	ND	100	ND	NA

% moisture = 20.3

C5 to C35 Hydrocarbons "Dry Weight Data"

Laboratory ID: 2924951

Sample ID: 13594

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	5	ND	0.1	ND	NA
VRH 2 **	NA	NA	6.5	5	ND	0.1	6.6	NA
>C8 - <=C10	ND	10	ND	10	ND	10	ND	NA
>C10 - <=C12	25.1	10	17.4	10	ND	10	20.5	82%
>C12 - <=C16	32	25	ND	25	ND	25	ND	NA
>C16 - <=C21	ND	25	ND	25	ND	25	ND	NA
>C21 - <=C35	ND	63	ND	63	ND	63	ND	NA
Total >C8 - <=C35	ND	125	ND	125	ND	125	ND	NA
Total >C5 - <=C35	NA	NA	ND	138	ND	125	ND	NA

* Volatile Range Hydrocarbons (Range 1 Aliphatics = C5 to C6 aliphatic (total) hydrocarbons)

Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2 Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)

Aromatics = >C7 to C8 aromatics (toluene only)

Prepared by Delwyn K Schumacher

HYDROCARBON SPECIATION PROJECT

C8 to C35 Hydrocarbons by Purge & Trap GC PID/FID
C5 to C8 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Extractable Batch ID: 981320002A

Laboratory ID: 2924952

Sample ID: 13595

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	2	ND	0.05	ND	NA
VRH 2 **	NA	NA	4.3	2	ND	0.05	4.3	NA
>C8 - <=C10	ND	8	ND	8	ND	8	ND	NA
>C10 - <=C12	8.7	8	ND	8	ND	8	ND	NA
>C12 - <=C16	ND	20	ND	20	ND	20	ND	NA
>C16 - <=C21	ND	20	ND	20	ND	20	ND	NA
>C21 - <=C35	ND	50	ND	50	ND	50	ND	NA
Total >C8 - <=C35	ND	100	ND	100	ND	100	ND	NA
Total >C5 - <=C35	NA	NA	ND	100	ND	100	ND	NA

% moisture = 21.9

C5 to C35 Hydrocarbons "Dry Weight Data"

Laboratory ID: 2924952

Sample ID: 13595

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	3	ND	0.06	ND	NA
VRH 2 **	NA	NA	5.5	3	ND	0.06	5.5	NA
>C8 - <=C10	ND	10	ND	10	ND	10	ND	NA
>C10 - <=C12	11.1	10	ND	10	ND	10	ND	NA
>C12 - <=C16	ND	26	ND	26	ND	26	ND	NA
>C16 - <=C21	ND	26	ND	26	ND	26	ND	NA
>C21 - <=C35	ND	64	ND	64	ND	64	ND	NA
Total >C8 - <=C35	ND	128	ND	128	ND	128	ND	NA
Total >C5 - <=C35	NA	NA	ND	128	ND	128	ND	NA

* Volatile Range Hydrocarbons (Range 1 Aliphatics = C5 to C6 aliphatic (total) hydrocarbons

Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2 Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)

Aromatics = >C7 to C8 aromatics (toluene only)

Prepared by Delwyn K Schumacher

HYDROCARBON SPECIATION PROJECT

C5 to C8 Hydrocarbons by Purge & Trap GC PID/FID
C8 to C35 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Extractable Batch ID: 98132002A

Laboratory ID: 2924953

Sample ID: 85-86

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	8	ND	0.2	ND	NA
VRH 2 **	NA	NA	8.8	8	ND	0.2	8.8	NA
>C8 - <=C10	15.8	8	9.5	8	ND	8	11.1	70%
>C10 - <=C12	27.6	8	13.9	8	ND	8	18.7	68%
>C12 - <=C16	23	20	ND	20	ND	20	ND	NA
>C16 - <=C21	ND	20	ND	20	ND	20	ND	NA
>C21 - <=C35	ND	50	ND	50	ND	50	ND	NA
Total >C8 - <=C35	ND	100	ND	100	ND	100	ND	NA
Total >C5 - <=C35	NA	NA	ND	120	ND	100	ND	NA

% moisture = 22.0

C5 to C35 Hydrocarbons "Dry Weight Data"

Laboratory ID: 2924953

Sample ID: 85-86

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	10	ND	0.3	ND	NA
VRH 2 **	NA	NA	11.3	10	ND	0.3	11.3	NA
>C8 - <=C10	20.3	10	12.1	10	ND	10	14.2	70%
>C10 - <=C12	35.4	10	17.8	10	ND	10	24.0	68%
>C12 - <=C16	30	26	ND	26	ND	26	ND	NA
>C16 - <=C21	ND	26	ND	26	ND	26	ND	NA
>C21 - <=C35	ND	64	ND	64	ND	64	ND	NA
Total >C8 - <=C35	ND	128	ND	128	ND	128	ND	NA
Total >C5 - <=C35	NA	NA	ND	154	ND	128	ND	NA

* Volatile Range Hydrocarbons (Range 1 Aliphatics = C5 to C6 aliphatic (total) hydrocarbons

Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2 Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)

Aromatics = >C7 to C8 aromatics (toluene only)

Prepared by Delwyn K Schumacher

HYDROCARBON SPECIATION PROJECT

C8 to C35 Hydrocarbons by Purge & Trap GC PID/FID
C5 to C8 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Extractable Batch ID: 981320002A

Laboratory ID: 2924954

Sample ID: 45-87

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	8	ND	0.2	ND	NA
VRH 2 **	NA	NA	ND	8	ND	0.2	ND	NA
>C8 - <=C10	ND	8	ND	8	ND	8	ND	NA
>C10 - <=C12	ND	8	ND	8	ND	8	ND	NA
>C12 - <=C16	ND	20	ND	20	ND	20	ND	NA
>C16 - <=C21	ND	20	ND	20	ND	20	ND	NA
>C21 - <=C35	ND	50	ND	50	ND	50	ND	NA
Total >C8 - <=C35	ND	100	ND	100	ND	100	ND	NA
Total >C5 - <=C35	NA	NA	ND	120	ND	100	ND	NA

% moisture = 19.8

C5 to C35 Hydrocarbons "Dry Weight Data"

Laboratory ID: 2924954

Sample ID: 45-87

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	10	ND	0.2	ND	NA
VRH 2 **	NA	NA	ND	10	ND	0.2	ND	NA
>C8 - <=C10	ND	10	ND	10	ND	10	ND	NA
>C10 - <=C12	ND	10	ND	10	ND	10	ND	NA
>C12 - <=C16	ND	25	ND	25	ND	25	ND	NA
>C16 - <=C21	ND	25	ND	25	ND	25	ND	NA
>C21 - <=C35	ND	62	ND	62	ND	62	ND	NA
Total >C8 - <=C35	ND	125	ND	125	ND	125	ND	NA
Total >C5 - <=C35	NA	NA	ND	150	ND	125	ND	NA

* Volatile Range Hydrocarbons (Range 1 Aliphatics = C5 to C6 aliphatic (total) hydrocarbons

Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2 Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)

Aromatics = >C7 to C8 aromatics (toluene only)

Prepared by Delwyn K Schumacher

HYDROCARBON SPECIATION PROJECT

C8 to C35 Hydrocarbons by Purge & Trap GC PID/FID
C5 to C8 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Extractable Batch ID: 981320002A

Laboratory ID: 2924955

Sample ID: 4587D

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	8	ND	0.2	ND	NA
VRH 2 **	NA	NA	ND	8	ND	0.2	ND	NA
>C8 - <=C10	ND	8	ND	8	ND	8	ND	NA
>C10 - <=C12	ND	8	ND	8	ND	8	ND	NA
>C12 - <=C16	ND	20	ND	20	ND	20	ND	NA
>C16 - <=C21	ND	20	ND	20	ND	20	ND	NA
>C21 - <=C35	ND	50	ND	50	ND	50	ND	NA
Total >C8 - <=C35	ND	100	ND	100	ND	100	ND	NA
Total >C5 - <=C35	NA	NA	ND	120	ND	100	ND	NA

% moisture = 22.6

C5 to C35 Hydrocarbons "Dry Weight Data"

Laboratory ID: 2924955

Sample ID: 4587D

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	10	ND	0.3	ND	NA
VRH 2 **	NA	NA	ND	10	ND	0.3	ND	NA
>C8 - <=C10	ND	10	ND	10	ND	10	ND	NA
>C10 - <=C12	ND	10	ND	10	ND	10	ND	NA
>C12 - <=C16	ND	26	ND	26	ND	26	ND	NA
>C16 - <=C21	ND	26	ND	26	ND	26	ND	NA
>C21 - <=C35	ND	65	ND	65	ND	65	ND	NA
Total >C8 - <=C35	ND	129	ND	129	ND	129	ND	NA
Total >C5 - <=C35	NA	NA	ND	155	ND	129	ND	NA

* Volatile Range Hydrocarbons (Range 1 Aliphatics = C5 to C6 aliphatic (total) hydrocarbons
Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2 Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)
Aromatics = >C7 to C8 aromatics (toluene only)

Prepared by Delwyn K Schumacher

HYDROCARBON SPECIATION PROJECT

C8 to C35 Hydrocarbons by Purge & Trap GC PID/FID
C5 to C8 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Extractable Batch ID: 981320002A

Laboratory ID: 2924956

Sample ID: 30-78

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	0.2	ND	0.005	ND	NA
VRH 2 **	NA	NA	ND	0.2	ND	0.005	ND	NA
>C8 - <=C10	ND	8	ND	8	ND	8	ND	NA
>C10 - <=C12	ND	8	ND	8	ND	8	ND	NA
>C12 - <=C16	ND	20	ND	20	ND	20	ND	NA
>C16 - <=C21	ND	20	ND	20	ND	20	ND	NA
>C21 - <=C35	ND	50	ND	50	ND	50	ND	NA
Total >C8 - <=C35	ND	100	ND	100	ND	100	ND	NA
Total >C5 - <=C35	NA	NA	ND	100	ND	100	ND	NA

% moisture = 21.9

C5 to C35 Hydrocarbons "Dry Weight Data"

Laboratory ID: 2924956

Sample ID: 30-78

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	0.3	ND	0.006	ND	NA
VRH 2 **	NA	NA	ND	0.3	ND	0.006	ND	NA
>C8 - <=C10	ND	10	ND	10	ND	10	ND	NA
>C10 - <=C12	ND	10	ND	10	ND	10	ND	NA
>C12 - <=C16	ND	26	ND	26	ND	26	ND	NA
>C16 - <=C21	ND	26	ND	26	ND	26	ND	NA
>C21 - <=C35	ND	64	ND	64	ND	64	ND	NA
Total >C8 - <=C35	ND	128	ND	128	ND	128	ND	NA
Total >C5 - <=C35	NA	NA	ND	128	ND	128	ND	NA

* Volatile Range Hydrocarbons (Range 1 Aliphatics = C5 to C6 aliphatic (total) hydrocarbons)

Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2 Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene))

Aromatics = >C7 to C8 aromatics (toluene only)

Prepared by Delwyn K Schumacher

HYDROCARBON SPECIATION PROJECT

C5 to C8 Hydrocarbons by Purge & Trap GC PID/FID
C8 to C35 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Extractable Batch ID: 981320002A

Laboratory ID: 2924957

Sample ID: 25-29

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	0.2	ND	0.005	ND	NA
VRH 2 **	NA	NA	ND	0.2	ND	0.005	ND	NA
>C8 - <=C10	ND	8	ND	8	ND	8	ND	NA
>C10 - <=C12	ND	8	ND	8	ND	8	ND	NA
>C12 - <=C16	ND	20	ND	20	ND	20	ND	NA
>C16 - <=C21	ND	20	ND	20	ND	20	ND	NA
>C21 - <=C35	ND	50	ND	50	ND	50	ND	NA
Total >C8 - <=C35	ND	100	ND	100	ND	100	ND	NA
Total >C5 - <=C35	NA	NA	ND	100	ND	100	ND	NA

% moisture = 17.2

C5 to C35 Hydrocarbons "Dry Weight Data"

Laboratory ID: 2924957

Sample ID: 25-29

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	0.2	ND	0.006	ND	NA
VRH 2 **	NA	NA	ND	0.2	ND	0.006	ND	NA
>C8 - <=C10	ND	10	ND	10	ND	10	ND	NA
>C10 - <=C12	ND	10	ND	10	ND	10	ND	NA
>C12 - <=C16	ND	24	ND	24	ND	24	ND	NA
>C16 - <=C21	ND	24	ND	24	ND	24	ND	NA
>C21 - <=C35	ND	60	ND	60	ND	60	ND	NA
Total >C8 - <=C35	ND	121	ND	121	ND	121	ND	NA
Total >C5 - <=C35	NA	NA	ND	121	ND	121	ND	NA

* Volatile Range Hydrocarbons (Range 1 Aliphatics = C5 to C6 aliphatic (total) hydrocarbons

Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2 Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)

Aromatics = >C7 to C8 aromatics (toluene only)

Prepared by Delwyn K Schumacher

HYDROCARBON SPECIATION PROJECT

C8 to C35 Hydrocarbons by Purge & Trap GC PID/FID
C5 to C8 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Extractable Batch ID: 981320002A

Laboratory ID: 2924958
Sample ID: 25-29MS

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	0.79	0.20	0.064	0.005	0.85	NA
VRH 2 **	NA	NA	0.96	0.20	0.378	0.005	1.34	NA
>C8 - <=C10	70.8	8	18.2	8	31.5	8	49.8	70%
>C10 - <=C12	49.9	8	19.6	8	17.3	8	36.9	74%
>C12 - <=C16	52	20	26	20	ND	20	43	82%
>C16 - <=C21	69	20	32	20	24	20	57	82%
>C21 - <=C35	103	50	ND	50	ND	50	82	80%
Total >C8 - <=C35	345	100	145	100	123	100	269	78%
Total >C5 - <=C35	NA	NA	147	100	124	100	271	NA

% moisture = 17.2

C5 to C35 Hydrocarbons "Dry Weight Data"

Laboratory ID: 2924958
Sample ID: 25-29MS

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	0.95	0.24	0.077	0.006	1.03	NA
VRH 2 **	NA	NA	1.16	0.24	0.457	0.006	1.62	NA
>C8 - <=C10	85.6	10	22.0	10	38.1	10	60.1	70%
>C10 - <=C12	60.2	10	23.6	10	20.9	10	44.5	74%
>C12 - <=C16	63	24	31	24	ND	24	52	82%
>C16 - <=C21	83	24	39	24	30	24	68	82%
>C21 - <=C35	125	60	ND	60	ND	60	99	80%
Total >C8 - <=C35	417	121	176	121	149	121	324	78%
Total >C5 - <=C35	NA	NA	178	121	149	121	327	NA

* Volatile Range Hydrocarbons (Range 1 Aliphatics = C5 to C6 aliphatic (total) hydrocarbons

Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2 Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)

Aromatics = >C7 to C8 aromatics (toluene only)

Prepared by Delwyn K Schumacher

HYDROCARBON SPECIATION PROJECT

C5 to C8 Hydrocarbons by Purge & Trap GC PID/FID
C8 to C35 Hydrocarbons by Pentane Extraction w/ Aliphatic/Aromatic Separation Performed on Silica Gel Column
"As Received (Wet Weight) Data"

Laboratory ID: 2924959
Sample ID: TB---

Approximate Carbon Number Range	TPH Pentane Extract (mg/kg)	LOQ	Aliphatic (mg/kg)	LOQ	Aromatic Hydrocarbons (mg/kg)	LOQ	Aliphatics + Aromatics (mg/kg)	Aliph + Arom Total (%)
VRH 1 *	NA	NA	ND	0.2	ND	0.005	ND	NA
VRH 2 **	NA	NA	ND	0.2	ND	0.005	ND	NA
>C8 - <=C10	NA	8	NA	8	NA	8	NA	NA
>C10 - <=C12	NA	8	NA	8	NA	8	NA	NA
>C12 - <=C16	NA	20	NA	20	NA	20	NA	NA
>C16 - <=C21	NA	20	NA	20	NA	20	NA	NA
>C21 - <=C35	NA	50	NA	50	NA	50	NA	NA
Total >C8 - <=C35	NA	100	NA	100	NA	100	NA	NA
Total >C5 - <=C35	NA	NA	ND	100	ND	100	ND	NA

* Volatile Range Hydrocarbons (Range 1 Aliphatics = C5 to C6 aliphatic (total)hydrocarbons

Aromatics = C6 to C7 aromatic hydrocarbons (benzene only)

** Volatile Range Hydrocarbons (Range 2 Aliphatics = >C6 to C8 aliphatic hydrocarbons (total minus benzene and toluene)

Aromatics = >C7 to C8 aromatics (toluene only)

NOTE: Extractable range hydrocarbons were not determined on this sample

Prepared by Delwyn K Schumacher

APPENDIX B RBSL CALCULATIONS

The procedure for calculating a TPH RBSL for cross-media pathways based upon summing the risk from each fraction is complex. Please note that the following procedure is only appropriate for calculation of RBSLs for cross-media pathways since it sets as an upper limit for the RBSL the degree of saturation, which does not limit exposure for direct routes such as soil ingestion, dermal exposure, and inhalation of particulates. An additional procedure used to calculate exposure for direct pathways is provided later.

Cross-media Pathways

Partitioning qualities govern how a chemical interacts with its environment. Specific physical properties responsible include solubility, vapor pressure, sorption coefficient and Henry's Law Constant. A brief discussion of the role these parameters play in basic partitioning in the environment is provided in the following paragraphs. The fraction-specific values for each of the described fate and transport parameters is provided in Table 3-1. The equations used to develop these fate and transport properties is available in the TPH Criteria Working Group "Volume III. Selection of Representative TPH Fractions Based on Fate and Transport Considerations" (1998).

The solubility of aromatic hydrocarbons, for any EC number, is generally greater than that of aliphatic hydrocarbons, especially at high EC values. The variability in solubility around any given EC value is about an order of magnitude. The higher solubility of the aromatics means that aromatic hydrocarbons are more likely to be present as dissolved constituents in groundwater than are the corresponding aliphatic hydrocarbons.

The soil-water sorption coefficient (k_s) expresses the tendency of a chemical to be adsorbed onto a soil particle. The magnitude of the sorption coefficient for most soil/water systems is a function of the hydrophobicity of the chemical (as indicated by its solubility) and the organic carbon content of the soil. For non-ionic, hydrophobic chemicals such as petroleum hydrocarbons, the primary property found to control sorption is the organic carbon content (f_{oc}) of the soil.

In general, aliphatic fractions are more likely to remain bound to a soil particle than the aromatic fraction of an equivalent EC. This tendency was previously indicated by the low solubility observed for aliphatic fractions. The majority of $\log k_{oc}$ (carbon-water sorption coefficient) values presented in Table 3-1 were derived from the octanol-water partitioning coefficient.

There is very little difference in vapor pressure between aliphatic and aromatic constituents of an equivalent EC. In effect, the EC and vapor pressure are closely related. This relationship is expected because both EC and vapor pressure are largely functions of a compound's boiling point.

The Henry's law constant (H_c) is definable as an air-water partitioning coefficient and may be measured as the ratio of a compound's concentration in air to its concentration in water at equilibrium. Aliphatics and aromatics behave differently based on Henry's law constant. For

aromatic fractions, the Henry's law constant decreases with increasing EC; for aliphatic fractions, the Henry's law constant is virtually unaffected by EC. In general, aliphatic hydrocarbons are less soluble and more volatile than aromatic hydrocarbons. It is important to note, however, that benzene, an aromatic compound, is very volatile and more toxic than the corresponding aliphatic fractions. Therefore, when present, benzene is likely to drive risk calculations for pathways involving volatilization from soil or groundwater.

The parameters described above are combined into simple fate and transport models to evaluate the partitioning and migration of chemicals for the different applicable pathways. For leaching and volatilization pathways where transport and therefore exposure are maximized at the saturation concentration for specific fractions, the following equation is solved:

$$HI = \sum_{i=1}^{i=n} HQ_i = \text{Min} \left(\sum_{i=1}^{i=n} \frac{f_i C_{TPH}}{RBSL_i}, \sum_{i=1}^{i=n} \frac{C_{i sat}}{RBSL_i} \right) \leq 1 \quad \text{given that,}$$

$$\sum_{i=1}^{i=13} f_i = \sum_{i=1}^{i=n} \frac{C_i}{C_{TPH}} = 1$$

where,

HI	=	Hazard Index (typically ≤ 1) [unitless]
n	=	number of fractions (13 total) [unitless]
HQ	=	Hazard Quotient for each specific fraction [unitless]
f	=	Percent Weight of each TPH fraction in total TPH mixture [unitless]
$C_{i sat}$	=	Saturation concentration for i^{th} TPH fraction (mg/kg)
$RBSL_i$	=	Tier 1 risk-based screening level for i^{th} TPH fraction (mg/kg)
C_{TPH}	=	Concentration of TPH mixture

The saturation concentration is defined by the following equation:

$$C_{sat} \left[\frac{\text{mg}}{\text{kg}} \right] = \frac{S}{\rho_s} * [H_c \theta_{as} + \theta_{ws} + k_s \rho_s]$$

where:

S	=	Fraction effective solubility [mg/L]
ρ_s	=	Soil Bulk Density [g/cm ³]
H_c	=	Henry's Constant [atm-m ³ /mol]
θ_{as}	=	Volumetric air content of the soil [cm ³ /cm ³]
θ_{ws}	=	Volumetric water content of the soil [cm ³ /cm ³]
k_s	=	Soil sorption coefficient ($k_{oc} * f_{oc}$) [cm ³ /g]

Note: The effective solubility of a hydrocarbon fraction is equal to the fraction's solubility limit multiplied by the mole fraction of the hydrocarbon fraction in the mixture (i.e., TPH).

The value obtained for C_{sat} will vary considerably if the effective C_{sat} of each fraction present in the sample is considered through the use of Raoult's law. The two equations above are iteratively solved for each TPH fraction, which is the additive mixture RBSL for the soil sample.

Residual saturation is the point at which any increase in chemical concentration will not change the risk, up until the point at which free product migration becomes an issue. For purposes of comparing RBSLs obtained using different analytical fractionation methods, such as the MADEP TPH Method, Raoult's law was not used to calculate the RBSLs presented in the following sections.

Soil Leaching to Groundwater Pathway

Leaching of contaminants from impacted soil into groundwater through infiltrating water is one exposure pathway evaluated in the RBCA analysis. Soil RBSLs are calculated to be protective of groundwater quality. This involves: 1) calculating a groundwater RBSL ($RBSL_{gw}$) to determine an acceptable water concentration, 2) calculating a leachate concentration protective of groundwater (based on the groundwater RBSL), and 3) calculating a soil concentration which would result in this leachate concentration. The following equation calculates the $RBSL_{gw}$ for ingestion.

$$RBSL_{gw} \left[\frac{mg}{L-water} \right] = \frac{THQ \times RfD_o \times BW \times AT_n \times 365 \frac{days}{yr}}{IR_{water} \times EF \times ED}$$

where:

THQ	=	Target hazard quotient [unitless]
RfD _o	=	Oral chronic reference dose [mg/kg-day]
BW	=	Body weight [kg]
AT _n	=	Averaging time for noncarcinogens [yrs]
IR _{water}	=	Daily ingestion rate [L/day]
EF	=	Exposure frequency [days/yr]
ED	=	Exposure Duration [yrs]

The $RBSL_{gw}$ is based on a target hazard quotient of 1.0. Exposure parameters are provided in Table B-1. RfDs for the fractions are listed in Table 3-2.

TABLE B-1 TIER 1 DEFAULT EXPOSURE FACTORS

Name	Parameter	Units	Residential Scenario	Commercial Scenario
Averaging Time: carcinogens	At _c	y	70	70
Averaging Time: non-carcinogens	At _n	y	30	25
Body Weight	BW	kg	70	70
Exposure Duration	ED	y	30	25
Exposure Frequency	EF	days/y	350	250
Ingestion rate: soil	IR _{soil}	mg/day	100	50
Inhalation Rate: air-indoor	IR _{air-in}	m ³ /day	20	20
Inhalation Rate: air-outdoor	IR _{air-out}	m ³ /day	20	20
Ingestion rate: water	IR _w	L/day	2	1
Soil Adherence Factor	M	mg/cm ²	0.5	0.5
Dermal Absorption Factor	RAF _d	-	c.s.	c.s.
Oral Absorption Factor	RAF _o	-	1	1
Skin surface area	SA	cm ² /day	3160	3160
Target Hazard Quotient for Individual Constituents.	THQ	-	1	1
Target Excess Ind. Lifetime Cancer Risk	TR	-	1E-06	1E-06

The analytical model used to estimate soil leaching to groundwater determines the partitioning of a constituent into water, vapor and sorbed phases based on the physical and chemical properties of the constituent. In this model, infiltrating water migrates through contaminated soils in the vadose zone. At this point, some of the contaminant partitions from the soil or vapor phase into the water phase. This leachate is then assumed to migrate completely and instantaneously into groundwater. Some dilution of the leachate is included using an attenuation factor based on infiltration rate, groundwater velocity, source width and height of the mixing zone in the water column. The equation describing this attenuation factor (AF) is as follows:

$$AF = \left[1 + \frac{U_{GW}\delta_{GW}}{IW} \right]$$

where:

- U_{GW} = Groundwater velocity [ft/day]
- δ_{GW} = Height of groundwater mixing zone [ft]
- I = Precipitation infiltration rate [ft/day]
- W = Width of the source area parallel to the mixing zone [ft]

Partitioning into the three phases, soil, water and air, is governed by the partitioning factor. As Henry's law constant is applicable only to dilute solutions, the use of this model is not appropriate when free phase liquid is present. The partitioning factor (PF) is shown below:

$$PF = \frac{[\theta_{ws} + k_s \rho_s + H_c \theta_{as}]}{\rho_s}$$

where,

θ_{ws}	=	Soil volumetric water content [cm ³ /cm ³]
k_s	=	Soil sorption coefficient ($k_{oc} * f_{oc}$) [cm ³ /g]
ρ_s	=	Soil density [g/cm ³]
H_c	=	Henry's Constant [atm-m ³ /mol]
θ_{as}	=	Soil volumetric air content [cm ³ /cm ³]

The PF multiplied by AF, which accounts for dilution of leached water into underlying groundwater, is termed the leaching factor (LF). The ultra-conservative leaching model assumes that no attenuation of leachate occurs from the vadose to the saturated zone. In fact, biological degradation of the constituent or repartitioning onto soil or into the vapor phase are all likely to occur as the leachate migrates to groundwater. Other assumptions of the model include: 1) a constant chemical concentration in the subsurface soils, 2) linear equilibrium partitioning within the soil matrix between sorbed, dissolved and vapor phases, 3) steady-state leaching from the vadose zone to groundwater, and 4) steady state, well-mixed dispersion of the leachate within the groundwater mixing zone. Therefore the LF, which governs the movement of contaminants from soil to infiltrating water, incorporates both the PF and the AF, in the following equation:

$$LF = \frac{\rho_s}{[\theta_{ws} + k_s + H\theta_{as}] \left(1 + \frac{U_{gw} \delta_{gw}}{IW} \right)}$$

where:

LF	=	leaching factor [mg/L-H ₂ O / mg/kg-soil]
U_{gw}	=	groundwater Darcy velocity [cm/yr]
δ_{gw}	=	groundwater mixing zone thickness [cm]
I	=	infiltration rate of water through soil [cm/yr]
W	=	width of source area parallel to groundwater flow direction [cm]

Parameters for the leaching pathway are provided in Table B-2. Once the LF has been established, fraction-specific soil RBSLs may be calculated as follows:

$$RBSL_s \left[\frac{mg}{kg-soil} \right] = \frac{RBSL_w \left[\frac{mg}{L-air} \right]}{LF_{sw}}$$

The fraction-specific RBSLs are then used to calculate "whole TPH" RBSLs.

Volatilization to Indoor Air Pathway

The mathematical model used to estimate volatilization from soil to indoor air is based upon the partitioning of a constituent into water, vapor and sorbed phases as determined by the physical

properties of the chemical. The model accounts for the contaminant partitioning into soil pore gas and migrating through the vadose zone to the base of a building foundation. From there the gas diffuses through cracks in the foundation and into the building air space, where exposure through inhalation may occur.

The first step in calculating a soil RBSL for the indoor air pathway requires the calculation of an air concentration or RBSL, which is protective of indoor air quality (based on a target HQ of 1.0). Indoor air RBSLs are calculated for each TPH fraction and then a whole TPH RBSL is calculated based on the percent composition of each fraction. The following equation is used to calculate the air RBSLs:

$$RBSL_{air} \left[\frac{\mu g}{m^3 \text{ air}} \right] = \frac{THQ \times RfD_i \times BW \times AT_n \times 365 \frac{days}{yr} \times 10^3 \frac{\mu g}{mg}}{IF_{air-in} \times EF \times ED}$$

where:

THQ	=	Target hazard quotient [unitless]
RfD _i	=	Inhalation chronic reference dose [mg/kg-day]
BW	=	Body weight [kg]
AT _n	=	Averaging time for noncarcinogens [yrs]
IF _{air-in}	=	Daily inhalation rate [m ³ /day]
EF	=	Exposure frequency [days/yr]
ED	=	Exposure Duration [years]

The second step in calculating a soil concentration (RBSL_{soil}) which will result in an acceptable indoor air concentration (RBSL_{air}) is to model the transport of contaminants from the vadose soil to indoor air. This model is extremely conservative, assuming: 1) a constant chemical concentration in subsurface soils; 2) linear equilibrium partitioning in the soil between sorbed, dissolved and vapor phases; and 3) steady-state vapor- and liquid-phase diffusion through the vadose zone and foundation cracks. In addition, the model assumes that vapors migrate completely and instantaneously into the building, i.e., no attenuation occurs. It does not account for any biodegradation and soil sorption which could occur as the vapor migrates through the vadose zone.

Dilution of vapor is expected to occur between the source and the building. Therefore the following diffusion factor is used:

$$D_s^{eff} \left[\frac{cm^2}{s} \right] = D^{air} \frac{\theta_{as}^{3.33}}{\theta_T^2} + D^{wat} \frac{1}{H_c} \times \frac{\theta_{ws}^{3.33}}{\theta_T^2}$$

where:

D ^{air}	=	Diffusion coefficient in air [cm ² /sec]
θ _{as}	=	Soil volumetric air content [cm ³ -air/cm ³ -soil]
θ _T	=	Total soil porosity [cm ³ /cm ³]
D ^{wat}	=	Diffusion coefficient in water [cm ² /sec]
H _c	=	Henry's constant [cm ³ -air/cm ³ -soil]
θ _{ws}	=	Soil volumetric water content [cm ³ -water/cm ³ -soil]

TABLE B-2 PARAMETERS FOR CROSS-MEDIA RBSL CALCULATIONS

Description	Parameter	Units	Tier 1 Default Values
Ambient air mixing zone height	δ_{air}	cm	200
Areal fraction of cracks in foundations/walls	η	cm ² /cm ²	0.01
Averaging time for vapor flux	τ	s	7.88E+8
Carbon-water sorption coefficient	k_{oc}	cm ³ /g	c.s.
Depth to groundwater (hcap+hv)	L_{GW}	cm	300
Depth to subsurface soil sources	L_s	cm	61
Diffusion coefficient in air	D^{air}	cm ² /s	c.s.
Diffusion coefficient in water	D^{wat}	cm ² /s	c.s.
Enclosed space air exchange rate	ER	1/s	0.00023
Enclosed space foundation or wall thickness	L_{crack}	cm	15
Enclosed space volume/infiltration area ratio	L_B	cm	300.
Fraction organic carbon in soil	f_{oc}	g/g	0.01
Groundwater Darcy velocity	μ_{gw}	cm/yr	2500
Groundwater mixing zone thickness	δ_{gw}	cm	200
Henry's Law Constant	H	(cm ³ /cm ³)	c.s.
Infiltration rate of water through soil	I	cm/yr	30
Lower depth of surficial soil zone	d	cm	100
Particulate emission rate	PE	g/cm ² -s	2.2E-10
Particulate Emission Rate	VF_p	(mg/m ³)/ (mg/kg)	6.90E-14
Pure component solubility in water	S	mg/L	c.s.
Soil bulk density	ρ	g/cm ³	1.7
Soil-water sorption coefficient	k_s	cm ³ /g	Foc*koc
Thickness of capillary fringe	h_{cap}	cm	5
Thickness of vadose zone	h_v	cm	295
Total soil porosity	θ_T	cm ³ /cm ³	0.38
Volatilization Factor	VF_i	(mg/m ³) (mg/m ³)	c.s. & m.s.
Volumetric air content in vadose zone soils	θ_{as}	cm ³ /cm ³	0.03
Volumetric air content in capillary fringe soils	θ_{acap}	cm ³ /cm ³	0.038
Volumetric air content in foundation cracks	θ_{acrack}	cm ³ /cm ³	0.26
Volumetric water content vadose zone soils	θ_{ws}	cm ³ /cm ³	0.12
Volumetric water content: capillary fringe	θ_{wcap}	cm ³ /cm ³	0.342
Volumetric water content: foundation cracks	θ_{wcrack}	cm ³ /cm ³	0.12
Width of source area parallel to flow direction	W	cm	1500
Wind speed above ground surface	U_{air}	cm/s	225

c.s. = chemical specific

m.s. = media specific

The diffusion of the pore gas through cracks in the foundation is governed by the following equation:

$$D_{crack}^{eff} \left[\frac{cm^2}{s} \right] = D^{air} \frac{\theta_{acrack}^{3.33}}{\theta_T^2} + D^{wat} \frac{1}{H_c} \times \frac{\theta_{wcrack}^{3.33}}{\theta_T^2}$$

where:

D^{air}	=	Diffusion coefficient in air [cm ² /sec]
θ_{acrack}	=	Volumetric air content in foundation [cm ³ -air/cm ³]
θ_T	=	Total soil porosity [cm ³ /cm ³]
D^{wat}	=	Diffusion coefficient in water [cm ² /sec]
H_c	=	Henry's constant [cm ³ -air/cm ³ -soil]
θ_{wcrack}	=	Volumetric water content in foundation [cm ³ -water/cm ³]

The default parameters used in these equations are provided in Table B-2.

Chemical Partitioning

The partitioning equation which accounts for the movement of chemicals from the soil into the vapor phase in the soil pore space is defined as the partitioning factor (soil/vapor phase) as follows:

$$PF_{S-v} = \frac{H_c \rho_s}{\theta_{ws} + k_s \rho_s + H_c \theta_{as}}$$

where:

PF_{S-v}	=	Soil/Vapor phase partitioning factor (unitless)
H_c	=	Henry's Constant [cm ³ -water/cm ³ -air]
ρ_s	=	Soil bulk density [g/cm ³]
θ_{ws}	=	Soil volumetric water content [cm ³ /cm ³]
k_s	=	Soil sorption coefficient ($k_{oc} * f_{oc}$) [cm ³ /g]
θ_{as}	=	Soil volumetric air content [cm ³ /cm ³]

The diffusion coefficients and partitioning factor are combined to yield a subsurface soil to enclosed space volatilization factor (VF_{seps}), which takes into account partitioning, diffusion in the vadose zone, effective diffusion into an enclosed space and adds terms for accumulation of vapors in the enclosed space. The VF is calculated as follows:

$$VF_{seps} = \frac{\frac{(PF_{S-v}) D_s^{eff}}{L_s(ER) L_B}}{1 + \frac{D_s^{eff}}{ER L_s} + \frac{D_s^{eff} + L_{crack}}{(L_s D_{crack}^{eff}) \times \eta}} \times 10^3 \left[\frac{cm^3 - kg}{m^3 - g} \right]$$

where:

PF_{S-v}	=	Soil/Vapor phase partitioning factor (unitless - see equation above)
D_s^{eff}	=	Effective diffusion coefficient in soil [cm ² /s]
L_s	=	Depth to subsurface soil sources [cm]

ER	=	Enclosed-space air exchange rate [s ⁻¹]
L _B	=	Enclosed-space volume/infiltration area ratio [cm]
D _{crack} ^{eff}	=	Effective diffusion coefficient through foundation cracks [cm ² /s]
L _{crack}	=	Enclosed-space foundation or wall thickness [cm]
η	=	Areal fraction of cracks in foundation/walls [cm ² /cm ²]

Values in these calculations are provided in Table B-2. The term VF_{seps}, when combined with the allowable concentration of contaminant in the air space (RBSL_{air}), determines the maximum allowable concentration in the subsurface soil source area as shown in the following equation:

$$RBSL_{soil} \left[\frac{mg}{kg-soil} \right] = \frac{RBSL_{air} \left[\frac{mg}{m^3-air} \right]}{VF_{seps}}$$

where:

RBSL_{soil} = Risk based screening level (volatilization to indoor air pathway)

Fraction-specific RBSLs are then used to calculate the "whole TPH" RBSLs.

Volatilization to Outdoor Air Pathway

The volatilization to outdoor air model is similar to the indoor air model. It assumes contaminants partition into soil pore gas which migrates through the vadose zone to the surface and mixes with the ambient air. Dispersion into ambient air is modeled using a "box model", which is typically valid for source widths of less than 100 feet parallel to wind direction. Steady-state well-mixed atmospheric dispersion of the vapors within the breathing zone is assumed. Other assumptions listed for the indoor air model include linear equilibrium partitioning, steady-state vapor diffusion through the vadose zone and no attenuation of the chemical as it migrates through the vadose zone.

The calculation of a soil RBSL protective of outdoor air quality is similar to that used for the indoor air pathway. A volatilization factor for ambient air (VF_{samb}) is derived, using the same effective diffusion coefficient in vadose soils and partitioning factor. Default values are provided in Table B-2.

$$VF_{samb} \left[\frac{mg/m^3-air}{mg/kg-soil} \right] = \frac{PF_{s-v}}{1 + \frac{U_{air} \delta_{air} L_s}{D_s^{eff} w}} \times 10^3 \left[\frac{cm^3 - kg}{m^3 - g} \right]$$

where:

PF _{s-v}	=	Soil/Vapor phase partitioning factor [unitless]
D _s ^{eff}	=	Effective diffusion coefficient in soil [cm ² /s]
U _{air}	=	Wind speed above ground surface in ambient mixing zone [cm/s]
δ _{air}	=	Ambient air mixing zone height [cm]
w	=	Width of source area parallel to wind direction [cm]

VF_{samb} is then combined with the allowable concentration of contaminant in the air space ($RBSL_{air}$) to determine the maximum allowable concentration of contaminant in the subsurface soil ($RBSL_{svout}$), as shown below:

$$RBSL_{svout} = \frac{RBSL_{air} \left[\frac{mg}{m^3 - air} \right]}{VF_{samb}}$$

Fraction-specific RBSLs are then used to calculate "whole TPH" RBSLs. Parameter values are presented in Table B-2.

Direct Contact Pathway

For direct exposure routes such as soil ingestion, dermal absorption and inhalation of particulates, exposure is not limited by C_{sat} . The assumption is made that intake will continue to increase linearly with soil loading beyond C_{sat} for ingestion, dermal and particulate inhalation pathways. For the direct contact pathways, the following equations are solved:

$$HI = \sum_{i=1}^{i=n} HQ_i = \sum_{i=1}^{i=n} \frac{f_i C_{TPH}}{RBSL_i} \leq 1$$

$$RBSL_{ss} \left[\frac{ug}{kg-soil} \right] = \frac{THQ \times BW \times AT_n \times 365 \frac{days}{yr}}{EF \times ED \times \left[\frac{10^{-6} \frac{kg}{mg} \times (IR_{soil} \times RAF_o \times SA \times M \times RAF_d)}{RfD_o} \right] + \left[\frac{IR_{air} \times (VF_{ss} + VF_p)}{RfD_i} \right]}$$

where:

THQ	=	Target hazard quotient for constituent [unitless]
BW	=	Body weight [kg]
AT_n	=	Averaging time for noncarcinogens [years]
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration [years]
IR_{soil}	=	Soil ingestion rate [mg/day]
RAF_o	=	Relative oral absorption factor [unitless]
SA	=	Skin surface area [cm ² /day]
M	=	Soil to skin adherence factor [mg/cm ²]
RAF_d	=	Relative dermal absorption factor [unitless]
RfD_o	=	Oral chronic reference dose [mg/kg-day]
IR_{air}	=	Inhalation rate [m ³ /day]
VF_{ss}	=	Surficial soils to ambient air partition factor (vapor) [unitless]
VF_p	=	Surficial soils to ambient air partition factor [unitless]
RfD_i	=	Inhalation chronic reference dose [mg/kg-day]

Similar to the HI calculation, the RBSL equation is solved iteratively to find C_{TPH} such that $HI=1$ under the constraint of a target hazard index of 1.0. Default exposure parameters are provided in Table B-1. The fraction specific RfDs are provided in Table 3-2.

2924948

RESIDENTIAL SCENARIO (using one-half LOQ for NDs)

Csat	RB.SL.R.11	RB.SL.R.16	RB.SL.R.16	RB.SL.R.18
(mg/kg)	s lch (mg/kg)	s v out (mg/kg)	s v in (mg/kg)	ss (mg/kg)
	HQ=1	HQ=1	HQ=1	HQ=1
5-6 Aliphatics	4.8E+02	2.9E+04	2.7E+03	5.4E+01
5-7 Aromatics	1.6E+03	8.1E+01	6.5E+02	1.3E+01
>6-8 Aliphatics	2.6E+02	1.1E+05	6.6E+03	1.3E+02
>7-8 Aromatics	1.3E+03	2.2E+02	1.5E+03	2.9E+01
>8-10 Aliphatics	1.4E+02	1.5E+04	1.7E+03	3.4E+01
>8-10 Aromatics	1.0E+03	2.8E+02	2.3E+03	4.6E+01
>10-12 Aliphatics	8.6E+01	1.1E+05	8.2E+03	1.6E+02
>10-12 Aromatics	6.3E+02	4.5E+02	1.3E+04	2.5E+02
>12-16 Aliphatics	3.8E+01	2.2E+06	3.9E+04	7.8E+02
>12-16 Aromatics	2.9E+02	8.9E+02	6.5E+04	3.0E+03
>16-21 Aliphatics	1.3E+01	8.8E+09	4.4E+06	1.5E+05
>16-21 Aromatics	8.1E+01	2.1E+03	5.6E+05	2.4E+03
>21-35 Aromatics	8.3E+00	1.7E+04	7.7E+07	2.5E+03

COMMERCIAL SCENARIO (using one-half LOQ for NDs)

Csat	RB.SL.R.11	RB.SL.R.16	RB.SL.R.16	RB.SL.R.18
(mg/kg)	s lch (mg/kg)	s v out (mg/kg)	s v in (mg/kg)	ss (mg/kg)
	Non-Carc	Non-Carc	Non-Carc	Non-Carc
5-6 Aliphatics	4.8E+02	8.2E+04	3.8E+03	1.4E+02
5-7 Aromatics	1.6E+03	2.3E+02	9.1E+02	3.3E+01
>6-8 Aliphatics	2.6E+02	3.0E+05	9.2E+03	3.4E+02
>7-8 Aromatics	1.3E+03	6.1E+02	2.1E+03	7.5E+01
>8-10 Aliphatics	1.4E+02	4.1E+04	2.4E+03	8.7E+01
>8-10 Aromatics	1.0E+03	7.9E+02	3.2E+03	1.2E+02
>10-12 Aliphatics	8.6E+01	3.1E+05	1.1E+04	4.2E+02
>10-12 Aromatics	6.3E+02	1.2E+03	1.8E+04	6.5E+02
>12-16 Aliphatics	3.8E+01	6.2E+06	5.5E+04	2.0E+03
>12-16 Aromatics	2.9E+02	2.5E+03	9.1E+04	3.4E+03
>16-21 Aliphatics	1.3E+01	2.5E+10	6.1E+06	2.3E+05
>16-21 Aromatics	8.1E+01	5.9E+03	7.8E+05	2.9E+04
>21-35 Aromatics	8.3E+00	4.7E+04	1.1E+08	4.0E+06

Fraction
(mg/kg/mg/kg)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

Fraction
(mg/kg/mg/kg)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

HQ(Ci)

COMMERCIAL SCENARIO (using one-half LOQ for NDs)

2924949		RESIDENTIAL SCENARIO (using one-half LOQ for NDs)					COMMERCIAL SCENARIO (using one-half LOQ for NDs)				
	Csat	RBSL.R.11	RBSL.R.16	RBSL.R.16	RBSL.R.18		Csat				
	(mg/kg)	s lch	s v out	s v in	ss		(mg/kg)	s lch	s v out	s v in	ss
		HQ=1	HQ=1	HQ=1	HQ=1			Non-Carc	Non-Carc	Non-Carc	Non-Carc
5-6 Aliphatics	4.8E+02	2.9E+04	2.7E+03	5.4E+01	3.5E+05	5-6 Aliphatics	4.8E+02	8.2E+04	3.8E+03	1.4E+02	5.2E+05
5-7 Aromatics	1.6E+03	8.1E+01	6.5E+02	1.3E+01	1.2E+04	5-7 Aromatics	1.6E+03	2.3E+02	9.1E+02	3.3E+01	1.8E+04
>6-8 Aliphatics	2.6E+02	1.1E+05	6.6E+03	1.3E+02	3.5E+05	>6-8 Aliphatics	2.6E+02	3.0E+05	9.2E+03	3.4E+02	5.2E+05
>7-8 Aromatics	1.3E+03	2.2E+02	1.5E+03	2.9E+01	1.2E+04	>7-8 Aromatics	1.3E+03	6.1E+02	2.1E+03	7.5E+01	1.8E+04
>8-10 Aliphatics	1.4E+02	1.5E+04	1.7E+03	3.4E+01	7.8E+03	>8-10 Aliphatics	1.4E+02	4.1E+04	2.4E+03	8.7E+01	1.2E+04
>8-10 Aromatics	1.0E+03	2.8E+02	2.3E+03	4.6E+01	2.9E+03	>8-10 Aromatics	1.0E+03	7.9E+02	3.2E+03	1.2E+02	4.3E+03
>10-12 Aliphatics	8.6E+01	1.1E+05	8.2E+03	1.6E+02	7.8E+03	>10-12 Aliphatics	8.6E+01	3.1E+05	1.1E+04	4.2E+02	1.2E+04
>10-12 Aromatics	6.3E+02	4.5E+02	1.3E+04	2.5E+02	2.9E+03	>10-12 Aromatics	6.3E+02	1.2E+03	1.8E+04	6.5E+02	4.3E+03
>12-16 Aliphatics	3.8E+01	2.2E+06	3.9E+04	7.8E+02	7.8E+03	>12-16 Aliphatics	3.8E+01	6.2E+06	5.5E+04	2.0E+03	1.2E+04
>12-16 Aromatics	2.9E+02	8.9E+02	6.5E+04	1.3E+03	3.0E+03	>12-16 Aromatics	2.9E+02	2.5E+03	9.1E+04	3.4E+03	4.4E+03
>16-21 Aliphatics	1.3E+01	8.8E+09	4.4E+06	8.7E+04	1.5E+05	>16-21 Aliphatics	1.3E+01	2.5E+10	6.1E+06	2.3E+05	2.2E+05
>16-21 Aromatics	8.1E+01	2.1E+03	5.6E+05	1.1E+04	2.4E+03	>16-21 Aromatics	8.1E+01	5.9E+03	7.8E+05	2.9E+04	3.5E+03
>21-35 Aromatics	8.3E+00	1.7E+04	7.7E+07	1.5E+06	2.5E+03	>21-35 Aromatics	8.3E+00	4.7E+04	1.1E+08	4.0E+06	3.6E+03

[illegible]

RBSL Model Runs

2924948	RESIDENTIAL SCENARIO (using zero for NDs)					COMMERCIAL SCENARIO (using zero for NDs)				
	Csat	RBSL.R.11	RBSL.R.16	RBSL.R.16	RBSL.R.18	Csat	1.1E+01	1.6E+01	1.6E+01	1.8E+01
	(mg/kg)	s lch	s v out	s v in	ss	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	ss
		HQ=1	HQ=1	HQ=1	HQ=1		Non-Carc	Non-Carc	Non-Carc	Non-Carc
5-6 Aliphatics	4.8E+02	2.9E+04	2.7E+03	5.4E+01	3.5E+05	4.8E+02	8.2E+04	3.8E+03	1.4E+02	5.2E+05
5-7 Aromatics	1.6E+03	8.1E+01	6.5E+02	1.3E+01	1.2E+04	1.6E+03	2.3E+02	9.1E+02	3.3E+01	1.8E+04
>6-8 Aliphatics	2.6E+02	1.1E+05	6.6E+03	1.3E+02	3.5E+05	2.6E+02	3.0E+05	9.2E+03	3.4E+02	5.2E+05
>7-8 Aromatics	1.3E+03	2.2E+02	1.5E+03	2.9E+01	1.2E+04	1.3E+03	6.1E+02	2.1E+03	7.5E+01	1.8E+04
>8-10 Aliphatics	1.4E+02	1.5E+04	1.7E+03	3.4E+01	7.8E+03	1.4E+02	4.1E+04	2.4E+03	8.7E+01	1.2E+04
>8-10 Aromatics	1.0E+03	2.8E+02	2.3E+03	4.6E+01	2.9E+03	1.0E+03	7.9E+02	3.2E+03	1.2E+02	4.3E+03
>10-12 Aliphatics	8.6E+01	1.1E+05	8.2E+03	1.6E+02	7.8E+03	8.6E+01	3.1E+05	1.1E+04	4.2E+02	1.2E+04
>10-12 Aromatics	6.3E+02	4.5E+02	1.3E+04	2.5E+02	2.9E+03	6.3E+02	1.2E+03	1.8E+04	6.5E+02	4.3E+03
>12-16 Aliphatics	3.8E+01	2.2E+06	3.9E+04	7.8E+02	7.8E+03	3.8E+01	6.2E+06	5.5E+04	2.0E+03	1.2E+04
>12-16 Aromatics	2.9E+02	8.9E+02	6.5E+04	1.3E+03	3.0E+03	2.9E+02	2.5E+03	9.1E+04	3.4E+03	4.4E+03
>16-21 Aliphatics	1.3E+01	8.8E+09	4.4E+06	8.7E+04	1.5E+05	1.3E+01	2.5E+10	6.1E+06	2.3E+05	2.2E+05
>16-21 Aromatics	8.1E+01	2.1E+03	5.6E+05	1.1E+04	2.4E+03	8.1E+01	5.9E+03	7.8E+05	2.9E+04	3.5E+03
>21-35 Aromatics	8.3E+00	1.7E+04	7.7E+07	1.5E+06	2.5E+03	8.3E+00	4.7E+04	1.1E+08	4.0E+06	3.6E+03
	Fraction	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)	Fraction	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
	(mg/kg/mg/kg)					(mg/kg/mg/kg)				
5-6 Aliphatics	8.2E-03	1.2E-03	1.7E-01	1.7E-02	1.4E-04	8.2E-03	3.1E-03	1.2E-01	1.8E-02	1.4E-04
5-7 Aromatics	2.0E-04	1.1E-02	1.3E-01	1.8E-03	1.0E-04	2.0E-04	2.8E-02	2.9E-01	1.9E-03	1.0E-04
>6-8 Aliphatics	2.5E-02	9.9E-04	3.9E-02	2.2E-02	4.3E-04	2.5E-02	8.7E-04	2.8E-02	2.2E-02	4.3E-04
>7-8 Aromatics	2.0E-04	4.0E-03	5.6E-02	8.1E-04	1.0E-04	2.0E-04	1.0E-02	1.3E-01	8.2E-04	1.0E-04
>8-10 Aliphatics	2.0E-01	9.7E-03	8.4E-02	6.7E-01	1.5E-01	2.0E-01	3.5E-03	6.0E-02	6.8E-01	1.5E-01
>8-10 Aromatics	8.2E-03	1.2E-01	4.5E-01	2.1E-02	1.7E-02	8.2E-03	3.2E-01	3.2E-01	2.1E-02	1.7E-02
>10-12 Aliphatics	2.9E-01	7.7E-04	1.0E-02	2.0E-01	2.3E-01	2.9E-01	2.7E-04	7.5E-03	2.0E-01	2.3E-01
>10-12 Aromatics	5.1E-02	4.8E-01	5.0E-02	2.4E-02	1.1E-01	5.1E-02	5.0E-01	3.6E-02	2.4E-02	1.1E-01
>12-16 Aliphatics	2.1E-01	1.7E-05	9.7E-04	3.1E-02	1.6E-01	2.1E-01	6.1E-06	7.0E-04	1.9E-02	1.6E-01
>12-16 Aromatics	7.2E-02	3.3E-01	4.5E-03	6.4E-03	1.5E-01	7.2E-02	1.2E-01	3.2E-03	6.5E-03	1.5E-01
>16-21 Aliphatics	7.0E-02	1.5E-09	3.0E-06	9.2E-05	2.8E-03	7.0E-02	5.3E-10	2.1E-06	5.8E-05	2.8E-03
>16-21 Aromatics	2.0E-02	3.8E-02	1.5E-04	2.1E-04	5.2E-02	2.0E-02	1.4E-02	1.0E-04	2.2E-04	5.2E-02
>21-35 Aromatics	5.1E-02	5.0E-04	1.1E-07	3.8E-06	1.3E-01	5.1E-02	1.8E-04	7.7E-08	2.1E-06	1.3E-01
Total	1.0E+00					Total	1.0E+00			
	RBSL.R.11	RBSL.R.16	RBSL.R.16	RBSL.R.16	RBSL.R.18		1.1E+01	1.6E+01	1.6E+01	1.8E+01
	s lch	s v out	s v in	ss		s lch	s v out	s v in	ss	
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00
RBSL(HI=1) mg/kg	4.2E+03	4.0E+05	1.2E+02	6.1E+03		3.1E+04	1.3E+06	3.0E+02	9.0E+03	

RBSL Model Runs

2924949	RESIDENTIAL SCENARIO (using zero for NDs)									
	RBSL.R.11					RBSL.R.16				
	Csat	s lch	s v out	s v in	ss	Csat	s lch	s v out	s v in	ss
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)		(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
5-6 Aliphatics	4.8E+02	2.9E+04	2.7E+03	5.4E+01	3.5E+05	5-6 Aliphatics	4.8E+02	8.2E+04	3.8E+03	1.4E+02
5-7 Aromatics	1.6E+03	8.1E+01	6.5E+02	1.3E+01	1.2E+04	5-7 Aromatics	1.6E+03	2.3E+02	9.1E+02	3.3E+01
>6-8 Aliphatics	2.6E+02	1.1E+05	6.6E+03	1.3E+02	3.5E+05	>6-8 Aliphatics	2.6E+02	3.0E+05	9.2E+03	3.4E+02
>7-8 Aromatics	1.3E+03	2.2E+02	1.5E+03	2.9E+01	1.2E+04	>7-8 Aromatics	1.3E+03	6.1E+02	2.1E+03	7.5E+01
>8-10 Aliphatics	1.4E+02	1.5E+04	1.7E+03	3.4E+01	7.8E+03	>8-10 Aliphatics	1.4E+02	4.1E+04	2.4E+03	8.7E+01
>8-10 Aromatics	1.0E+03	2.8E+02	2.3E+03	4.6E+01	2.9E+03	>8-10 Aromatics	1.0E+03	7.9E+02	3.2E+03	1.2E+02
>10-12 Aliphatics	8.6E+01	1.1E+05	8.2E+03	1.6E+02	7.8E+03	>10-12 Aliphatics	8.6E+01	3.1E+05	1.1E+04	4.2E+02
>10-12 Aromatics	6.3E+02	4.5E+02	1.3E+04	2.5E+02	2.9E+03	>10-12 Aromatics	6.3E+02	1.2E+03	1.8E+04	6.5E+02
>12-16 Aliphatics	3.8E+01	2.2E+06	3.9E+04	7.8E+02	7.8E+03	>12-16 Aliphatics	3.8E+01	6.2E+06	5.5E+04	2.0E+03
>12-16 Aromatics	2.9E+02	8.9E+02	6.5E+04	1.3E+03	3.0E+03	>12-16 Aromatics	2.9E+02	2.5E+03	9.1E+04	3.4E+03
>16-21 Aliphatics	1.3E+01	8.8E+09	4.4E+06	8.7E+04	1.5E+05	>16-21 Aliphatics	1.3E+01	2.5E+10	6.1E+06	2.3E+05
>16-21 Aromatics	8.1E+01	2.1E+03	5.6E+05	1.1E+04	2.4E+03	>16-21 Aromatics	8.1E+01	5.9E+03	7.8E+05	2.9E+04
>21-35 Aromatics	8.3E+00	1.7E+04	7.7E+07	1.5E+06	2.5E+03	>21-35 Aromatics	8.3E+00	4.7E+04	1.1E+08	4.0E+06

COMMERCIAL SCENARIO (using zero for NDs)									
Csat					Csat				
s lch	s v out	s v in	ss		s lch	s v out	s v in	ss	
(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
5-6 Aliphatics	8.2E+04	3.8E+03	1.4E+02	5.2E+05	5-6 Aliphatics	8.2E+04	3.8E+03	1.4E+02	5.2E+05
5-7 Aromatics	2.3E+02	9.1E+02	3.3E+01	1.8E+04	5-7 Aromatics	2.3E+02	9.1E+02	3.3E+01	1.8E+04
>6-8 Aliphatics	3.0E+05	9.2E+03	3.4E+02	5.2E+05	>6-8 Aliphatics	3.0E+05	9.2E+03	3.4E+02	5.2E+05
>7-8 Aromatics	6.1E+02	2.1E+03	7.5E+01	1.8E+04	>7-8 Aromatics	6.1E+02	2.1E+03	7.5E+01	1.8E+04
>8-10 Aliphatics	4.1E+04	2.4E+03	8.7E+01	1.2E+04	>8-10 Aliphatics	4.1E+04	2.4E+03	8.7E+01	1.2E+04
>8-10 Aromatics	7.9E+02	3.2E+03	1.2E+02	4.3E+03	>8-10 Aromatics	7.9E+02	3.2E+03	1.2E+02	4.3E+03
>10-12 Aliphatics	3.1E+05	1.1E+04	4.2E+02	1.2E+04	>10-12 Aliphatics	3.1E+05	1.1E+04	4.2E+02	1.2E+04
>10-12 Aromatics	1.2E+03	1.8E+04	6.5E+02	4.3E+03	>10-12 Aromatics	1.2E+03	1.8E+04	6.5E+02	4.3E+03
>12-16 Aliphatics	6.2E+06	5.5E+04	2.0E+03	1.2E+04	>12-16 Aliphatics	6.2E+06	5.5E+04	2.0E+03	1.2E+04
>12-16 Aromatics	2.5E+03	9.1E+04	3.4E+03	4.4E+03	>12-16 Aromatics	2.5E+03	9.1E+04	3.4E+03	4.4E+03
>16-21 Aliphatics	2.5E+10	6.1E+06	2.3E+05	2.2E+05	>16-21 Aliphatics	2.5E+10	6.1E+06	2.3E+05	2.2E+05
>16-21 Aromatics	5.9E+03	7.8E+05	2.9E+04	3.5E+03	>16-21 Aromatics	5.9E+03	7.8E+05	2.9E+04	3.5E+03
>21-35 Aromatics	4.7E+04	1.1E+08	4.0E+06	3.6E+03	>21-35 Aromatics	4.7E+04	1.1E+08	4.0E+06	3.6E+03

2924949	RESIDENTIAL SCENARIO (using zero for NDs)									
	RBSL.R.11					RBSL.R.16				
	Csat	s lch	s v out	s v in	ss	Csat	s lch	s v out	s v in	ss
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)		(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
5-6 Aliphatics	4.8E+02	2.9E+04	2.7E+03	5.4E+01	3.5E+05	5-6 Aliphatics	4.8E+02	8.2E+04	3.8E+03	1.4E+02
5-7 Aromatics	1.6E+03	8.1E+01	6.5E+02	1.3E+01	1.2E+04	5-7 Aromatics	1.6E+03	2.3E+02	9.1E+02	3.3E+01
>6-8 Aliphatics	2.6E+02	1.1E+05	6.6E+03	1.3E+02	3.5E+05	>6-8 Aliphatics	2.6E+02	3.0E+05	9.2E+03	3.4E+02
>7-8 Aromatics	1.3E+03	2.2E+02	1.5E+03	2.9E+01	1.2E+04	>7-8 Aromatics	1.3E+03	6.1E+02	2.1E+03	7.5E+01
>8-10 Aliphatics	1.4E+02	1.5E+04	1.7E+03	3.4E+01	7.8E+03	>8-10 Aliphatics	1.4E+02	4.1E+04	2.4E+03	8.7E+01
>8-10 Aromatics	1.0E+03	2.8E+02	2.3E+03	4.6E+01	2.9E+03	>8-10 Aromatics	1.0E+03	7.9E+02	3.2E+03	1.2E+02
>10-12 Aliphatics	8.6E+01	1.1E+05	8.2E+03	1.6E+02	7.8E+03	>10-12 Aliphatics	8.6E+01	3.1E+05	1.1E+04	4.2E+02
>10-12 Aromatics	6.3E+02	4.5E+02	1.3E+04	2.5E+02	2.9E+03	>10-12 Aromatics	6.3E+02	1.2E+03	1.8E+04	6.5E+02
>12-16 Aliphatics	3.8E+01	2.2E+06	3.9E+04	7.8E+02	7.8E+03	>12-16 Aliphatics	3.8E+01	6.2E+06	5.5E+04	2.0E+03
>12-16 Aromatics	2.9E+02	8.9E+02	6.5E+04	1.3E+03	3.0E+03	>12-16 Aromatics	2.9E+02	2.5E+03	9.1E+04	3.4E+03
>16-21 Aliphatics	1.3E+01	8.8E+09	4.4E+06	8.7E+04	1.5E+05	>16-21 Aliphatics	1.3E+01	2.5E+10	6.1E+06	2.3E+05
>16-21 Aromatics	8.1E+01	2.1E+03	5.6E+05	1.1E+04	2.4E+03	>16-21 Aromatics	8.1E+01	5.9E+03	7.8E+05	2.9E+04
>21-35 Aromatics	8.3E+00	1.7E+04	7.7E+07	1.5E+06	2.5E+03	>21-35 Aromatics	8.3E+00	4.7E+04	1.1E+08	4.0E+06

COMMERCIAL SCENARIO (using zero for NDs)									
Csat					Csat				
s lch	s v out	s v in	ss		s lch	s v out	s v in	ss	
(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
5-6 Aliphatics	8.2E+04	3.8E+03	1.4E+02	5.2E+05	5-6 Aliphatics	8.2E+04	3.8E+03	1.4E+02	5.2E+05
5-7 Aromatics	2.3E+02	9.1E+02	3.3E+01	1.8E+04	5-7 Aromatics	2.3E+02	9.1E+02	3.3E+01	1.8E+04
>6-8 Aliphatics	3.0E+05	9.2E+03	3.4E+02	5.2E+05	>6-8 Aliphatics	3.0E+05	9.2E+03	3.4E+02	5.2E+05
>7-8 Aromatics	6.1E+02	2.1E+03	7.5E+01	1.8E+04	>7-8 Aromatics	6.1E+02	2.1E+03	7.5E+01	1.8E+04
>8-10 Aliphatics	4.1E+04	2.4E+03	8.7E+01	1.2E+04	>8-10 Aliphatics	4.1E+04	2.4E+03	8.7E+01	1.2E+04
>8-10 Aromatics	7.9E+02	3.2E+03	1.2E+02	4.3E+03	>8-10 Aromatics	7.9E+02	3.2E+03	1.2E+02	4.3E+03
>10-12 Aliphatics	3.1E+05	1.1E+04	4.2E+02	1.2E+04	>10-12 Aliphatics	3.1E+05	1.1E+04	4.2E+02	1.2E+04
>10-12 Aromatics	1.2E+03	1.8E+04	6.5E+02	4.3E+03	>10-12 Aromatics	1.2E+03	1.8E+04	6.5E+02	4.3E+03
>12-16 Aliphatics	6.2E+06	5.5E+04	2.0E+03	1.2E+04	>12-16 Aliphatics	6.2E+06	5.5E+04	2.0E+03	1.2E+04
>12-16 Aromatics	2.5E+03	9.1E+04	3.4E+03	4.4E+03	>12-16 Aromatics	2.5E+03	9.1E+04	3.4E+03	4.4E+03
>16-21 Aliphatics	2.5E+10	6.1E+06	2.3E+05	2.2E+05	>16-21 Aliphatics	2.5E+10	6.1E+06	2.3E+05	2.2E+05
>16-21 Aromatics	5.9E+03	7.8E+05	2.9E+04	3.5E+03	>16-21 Aromatics	5.9E+03	7.8E+05	2.9E+04	3.5E+03
>21-35 Aromatics	4.7E+04	1.1E+08	4.0E+06	3.6E+03	>21-35 Aromatics	4.7E+04	1.1E+08	4.0E+06	3.6E+03